ASPEN ICARUS PROCESS EVALUATOR (IPE)

Equipment Sizing and Costing Using ASPEN PLUS to Initiate Evaluation

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INTRODUCTION

These notes are prepared to provide a step-by-step procedure for estimation of the total capital investment using the Aspen Icarus Process Evaluator (Aspen IPE). Aspen IPE is a software system provided by Aspen Technology, Inc., for economic evaluation of process designs. It determines the capital expenditure, operating costs, and the profitability of proposed designs. Aspen IPE has an automatic, electronic *expert system* which links to process simulation programs. It is used to: (1) extend the results of process simulation, (2) generate rigorous size and cost estimates for processing equipment, (3) perform preliminary mechanical designs, and (4) estimate purchase and installation costs, indirect costs, the total capital investment, the engineering-procurement-construction planning schedule, and profitability analyses.

Aspen IPE usually begins with the results of a simulation from one of the major process simulators (e.g., ASPEN PLUS, HYSYS, CHEMCAD, and PRO/II), it being noted that users can, alternatively, provide equipment specifications and request investment analysis without using the process simulators. In these notes, only results from ASPEN PLUS are used to initiate Aspen IPE evaluations and only capital cost estimation is emphasized. Readers should refer to the *Aspen IPE User's Guide* (Click on *Documentation* in the *Help* menu of Aspen IPE) for detailed instructions, explanations, and for improvements in new versions of the software system.

These notes are organized as follows:

1. Instructions are provided to prepare an ASPEN PLUS simulation for use with Aspen IPE.

2. A depropanizer example is provided to illustrate the use of Aspen IPE. The depropanizer is a distillation tower to recover propane and lighter species from a normal-paraffins stream, as shown in Figure 1. The simulation flowsheet and selected results are shown in Appendix I and in the multimedia tutorial on the Wiley web site associated with this book (*ASPEN* → *Tutorials* → *Separation Principles* → *Flash and Distillation*). Also, a copy of the file, RADFRAC.bkp, is provided in the ASPEN folder on the Wiley web site.

3. Additional features of Aspen IPE are introduced for a more complete process, the monochlorobenzene (MCB) separation process, which is discussed in Sections 5.4 of the textbook (Seider et al., 2009). A copy of the simulation file, MCB.bkp, is provided in the ASPEN folder on the Wiley web site.

After completing these notes, to practice estimating capital costs using Aspen IPE, you may wish to solve Exercises 22.4 and 23.21 in the textbook.

In these notes, all of the calculations were carried out using Aspen IPE, Version 2006.0, with the design and cost basis date being the First Quarter 2006.

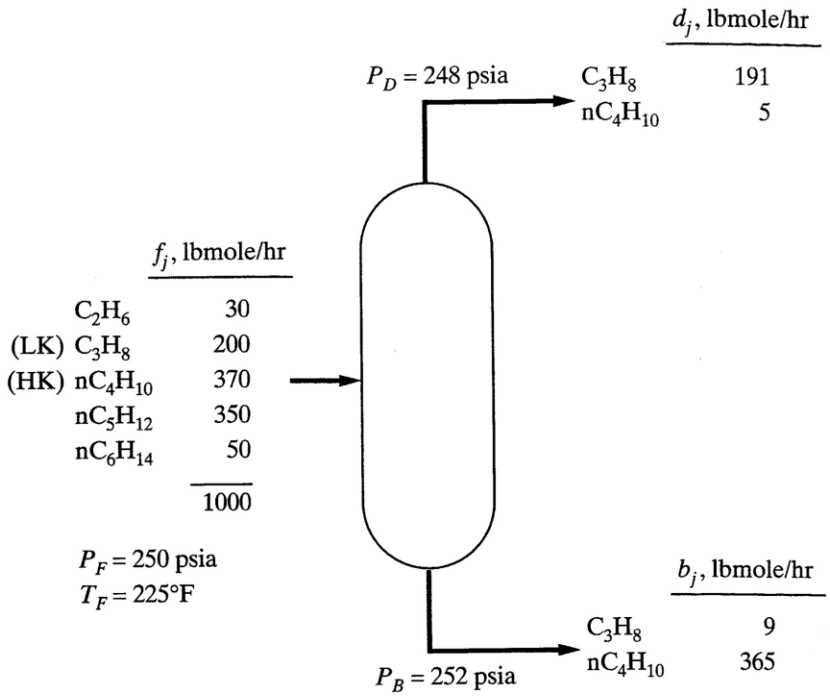


Figure 1 Depropanizer

PREPARING AN ASPEN PLUS SIMULATION FOR ASPEN IPE

To estimate equipment sizes and costs using Aspen IPE for a process simulated with ASPEN PLUS, it is necessary to prepare the simulation results for use with Aspen IPE. While this is accomplished in a similar manner for most of the major process simulators, these notes focus on the steps to prepare ASPEN PLUS simulations. For the steps when using the other process simulators, the reader should refer to the *Aspen IPE User's Guide* (click on *Documentation* in the *Help* menu of Aspen IPE).

It is normally necessary to adapt the simulation file in two ways. First, to estimate equipment sizes, Aspen IPE usually requires estimates of mixture properties not needed for the material and energy balance, and phase equilibria calculations performed by the process simulators. For this reason, it is necessary to augment the simulation report files with estimates of mixture properties, such as viscosity, thermal conductivity,

and surface tension, for the streams in the simulation flowsheet. Second, Aspen IPE requires specifications to estimate equipment sizes that are not computed by some of the approximate simulation models. This is the case, for example, when the DISTL and RSTOIC models are used in ASPEN PLUS. To circumvent this, these are replaced by more rigorous models, such as the RADFRAC and RPLUG models. This replacement can be viewed as the first step in computing equipment sizes and costs. Note that it is also possible to provide specifications for computing equipment sizes without using ASPEN PLUS.

Additional Mixture Properties

Estimates for the additional stream properties are added using the PROPSETS.apt file in the ASPEN folder on the Wiley web site associated with this book. To accomplish this, the ASPEN PLUS simulation file is opened first; e.g., RADFRAC.bkp (in the ASPEN folder on the Wiley web site). Under the *File* pull-down menu, the *Import* entry and the PROPSETS.apt file are selected. Aspen IPE automatically adds three new property sets, after which the file can be saved as RADFRAC-IPE.bkp, a copy of which is in the ASPEN folder on the Wiley web site. To check that this has been accomplished, using the *Data* pull-down menu, select *Setup* and then *Report Options*. Then, display the *Streams* page by selecting the appropriate tab and click the *Property Sets* button. Observe that all three Aspen IPE property sets have been entered into the *Selected Property Sets* box. Now that the Aspen IPE property sets have been added, it is necessary to re-run the simulation.

It remains to transfer the ASPEN PLUS simulation results into Aspen IPE. This is accomplished by selecting *Send To* → *Aspen Icarus* from the *File* pull-down menu in ASPEN PLUS. The simulation results are loaded automatically into Aspen IPE.

INVESTMENT ANALYSIS USING ASPEN IPE

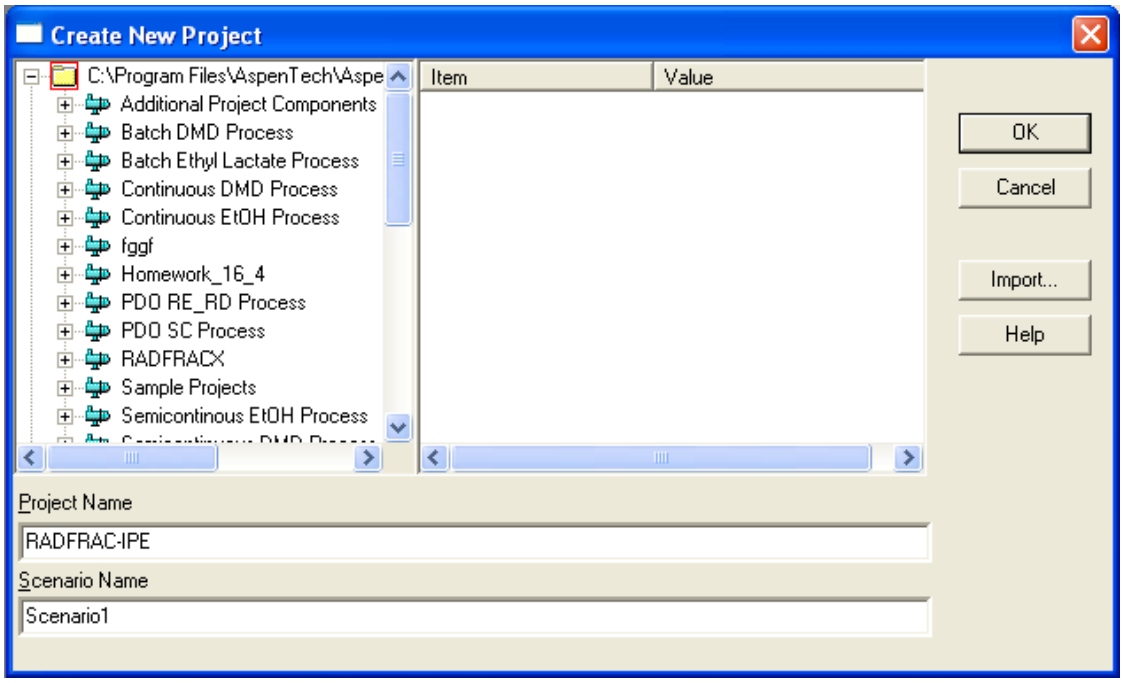
In this section, the use of Aspen IPE for equipment sizing and costing is illustrated for a depropanizer and for the monochlorobenzene separation process.

DEPROPANIZER

This example involves the single distillation column shown in Figure 1, with its simulation flowsheet and selected results shown in Appendix I and in the multimedia tutorial on the Wiley web site associated with this book (*ASPEN* → *Tutorials* → *Separation Principles* → *Flash and Distillation*).

Initial Setup

Having sent the ASPEN PLUS simulation file to Aspen IPE, it is opened automatically and the *Create New Project* dialog box appears:



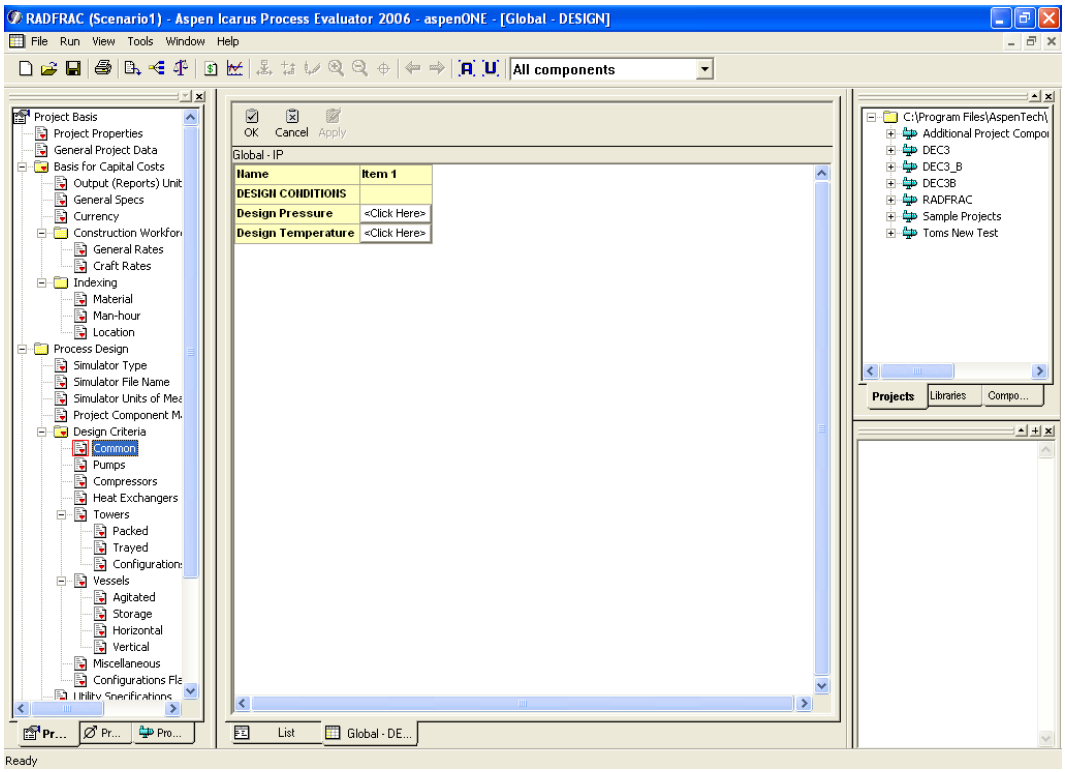
The user can either select an existing project in which to start a new scenario, or enter a new *Project Name*. The *Project Name* RADFRAC-IPE is assigned automatically from the ASPEN PLUS file name, however punctuation marks are not allowed, so enter the *Project Name* DEC3 instead. Note that the underscore and space characters are permitted. After pressing the *OK* button, the first of four dialog boxes, not shown here, appear. The first is the *Project Properties* dialog box, in which a *Project Description* and further remarks may be entered. A units of measure set is also chosen, which for this example is the *Inch-Pound* (IP) units set.

Second, the *Input Units of Measure Specifications* dialog box is displayed. This form allows the user to customize the units of measure that will appear on input specification forms. Click the *Close* button to accept the default settings.

Third, the *General Project Data* dialog box appears. Since no adjustments are needed in this example, press the *OK* button. Fourth, the *Load Simulator Data?* dialog box is displayed. Enter *Yes* to do so.

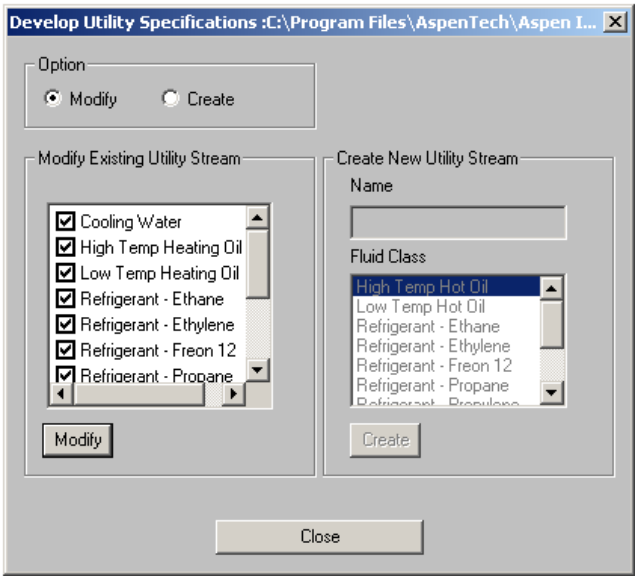
Aspen IPE now opens two windows shown below. The narrow *Project Explorer*, on the left, is in *Project View* mode, and a wider *Main* window, initially blank, is on the right. When they are not opened by default, two additional windows, *Palette* and *Property*, can be opened using the *View* pulldown menu. Aspen IPE allows the user to specify many parameters for equipment sizing or to accept default values. These are the bases for sizing the equipment and for specifying its utilities. The first step in completing this simulation is to examine the project *Design Criteria*. This can be done by selecting the *Project Basis View* tab in the *Project Explorer*. Note that the *Design Criteria* and *Utility Specifications* entries under the *Process Design* heading are the most relevant when estimating equipment sizes and costs. When it is not already open, double-click on

Design Criteria to expand its folder. Then, double-click on *Common* to cause the *Global-IP* form to appear in the *Main* window:

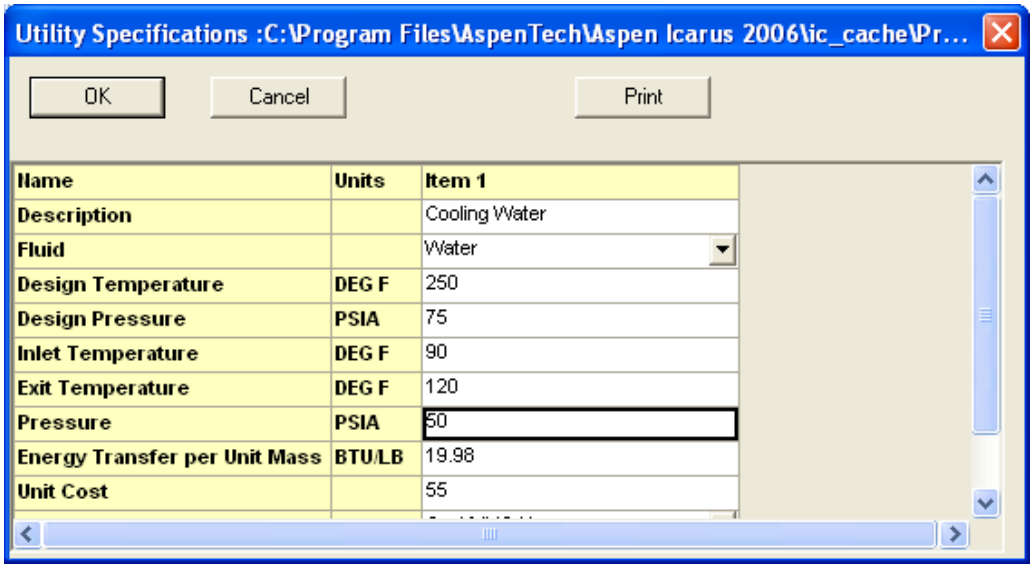


Default values are provided for many of the entries in the forms under *Design Criteria*. These can be modified as necessary, and missing entries can be entered. Particular attention should be paid to the design pressure and temperature, to the overdesign factors, to the residence times in the process vessels, as well as to other tower information. The user must be careful to check all of the relevant specifications that apply to the equipment under study. Note that the design criteria are defined in the *Aspen IPE User's Guide*, which can be accessed from the *Documents* entry in the *Help* menu in Aspen IPE, with the values specified for the depropanizer process shown in Appendix II (*Defining the Project Basis* → *Process Design* → *Design Criteria*). Note also that design criteria files can be created for use with other design projects. For implementation details, see the *Aspen IPE User's Guide*.

Also, it is usually important to examine the default values associated with the utilities. For this purpose, the *Utility Specifications* entry under the *Process Design* heading is selected to produce the *Develop Utility Specifications* dialog box:

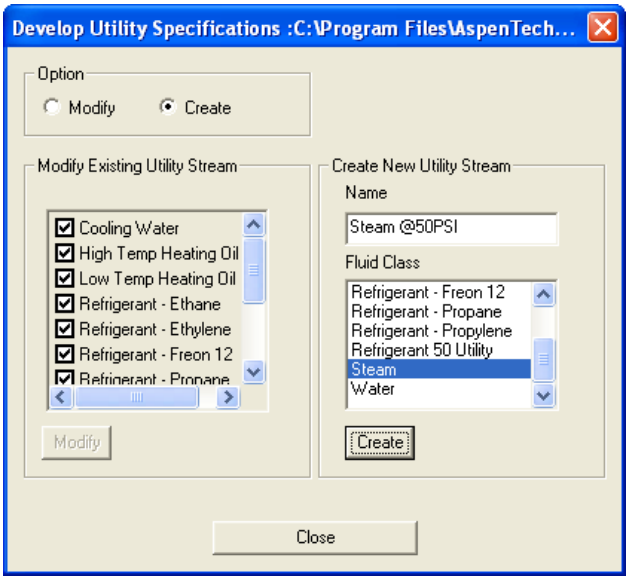


Note that all existing utilities to be used by Aspen IPE are listed. Default values should be examined and modified, and missing utilities should be added. For example, because the textbook recommends that process designs accept cooling water at 90°F and heat it to 120°F, it is necessary to replace the temperatures associated with the cooling water utility. To modify these temperatures, double-click on the *Cooling Water* entry, which produces the *Utility Specifications* dialog box:

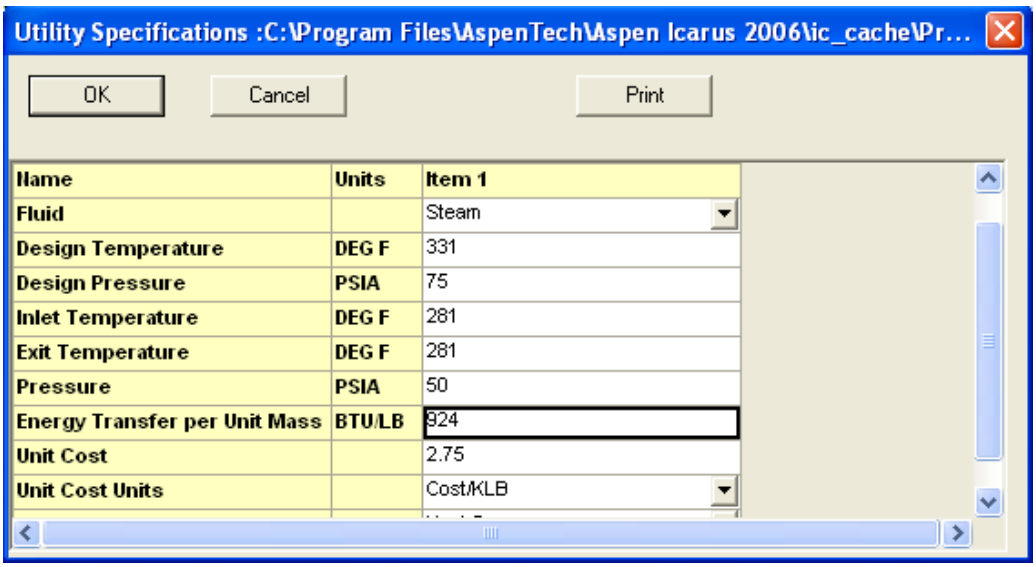


Then, the inlet and exit temperatures are changed to 90 and 120°F as shown above. Other default values can be changed similarly. Click *OK* when finished.

To add a utility not in the existing utility list, click on the *Create* option on the *Develop Utility Specifications* dialog box. As shown below, low-pressure steam is added as a *utility*, which is named *Steam @50PSI* and has the *Steam Fluid Class.*



After the *Create* button is pressed, the new utility is displayed as shown below, where the entries have already been made from the steam tables of Smith et al. (2001).



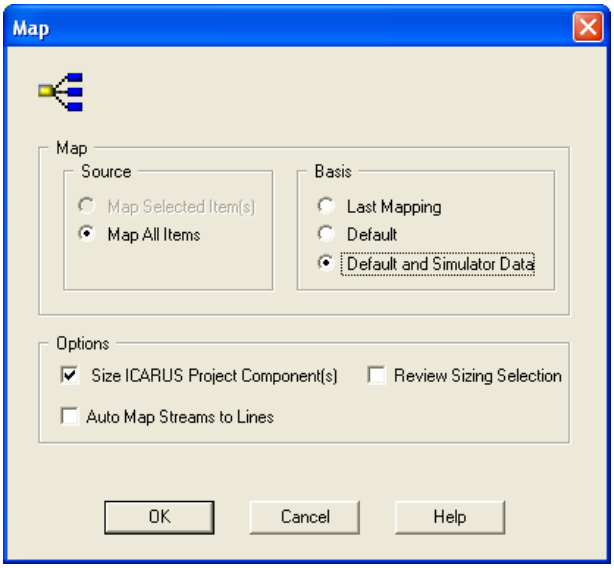
Name	Units	Item 1
Fluid		Steam
Design Temperature	DEG F	331
Design Pressure	PSIA	75
Inlet Temperature	DEG F	281
Exit Temperature	DEG F	281
Pressure	PSIA	50
Energy Transfer per Unit Mass	BTU/LB	924
Unit Cost		2.75
Unit Cost Units		Cost/KLB

When complete, the *OK* button is pressed to return to the *Develop Utility Specification* dialog box. Then, the *Close* button is pressed to return to the IPE *Main* window. Note that utility files can be created for use on other design projects. For implementation details, see the *Aspen IPE User's Guide*.

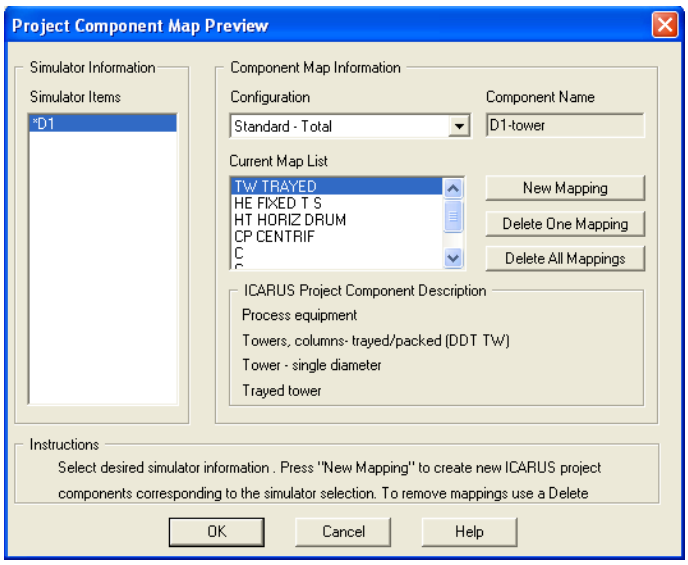
Other specifications can be changed in a manner similar to those described for the utilities and design criteria. More information and definitions are provided in the *Aspen IPE User's Guide* (*Defining the Project Basis → Process Design*).

Mapping Process Simulation Units into Aspen IPE

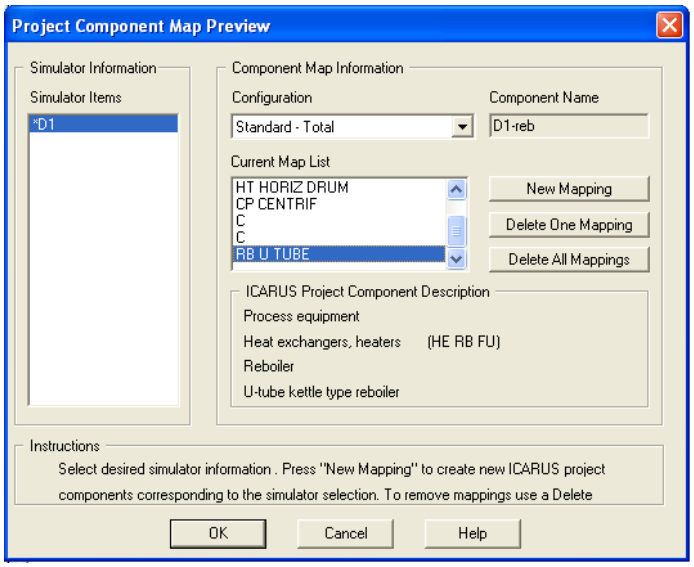
Having completed the initial setup, the next step is to map the process simulation units (that is, blocks, modules, or subroutines) into more descriptive models of process equipment (e.g., mapping a HEATX simulation unit into a floating-head, shell-and-tube heat exchanger; mapping a RADFRAC simulation unit into a tray tower, condenser, reflux accumulator, etc.) and associated *plant bulks*, which include installation items, such as piping, instrumentation, insulation, paint, etc. After Aspen IPE completes the mapping and reserves storage for the installation items, equipment sizes are computed. Note that the mapping and equipment sizing steps are accomplished in sequence, with sizes and costs of the installation items estimated during the *Equipment Costing* step. To begin the mapping step in the IPE *Main* window, the *Map Simulator Items* button on the toolbar is pressed to produce the *Map* dialog box:



For the depropanizer, all items are mapped and sized in sequence, since the *Size ICARUS Project Components* button is checked. When this button is not checked, only the mapping step is completed. Also, when there are multiple process units of a certain type, it may be preferable to map each process unit independently. For example, if two distillation towers differ in tray efficiency, it is necessary to map them separately and change the tray efficiency under *Design Criteria* before each tower is mapped. In this case, with just one tower, it is simplest to press the *Map all Items* button under *Source*. Under *Basis*, the *Default and Simulator Data* button should be selected, as shown. After pressing *OK*, the *Project Component Map Preview* dialog box is produced:

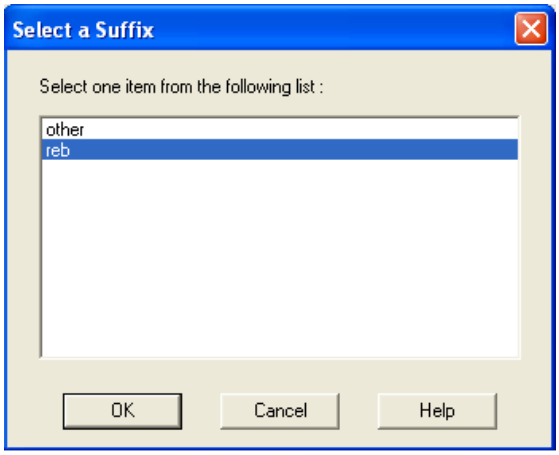


For each *Simulator Item* (*unit* or *block*), the *Current Map List* shows all corresponding equipment items in Aspen IPE. Observe that for the default configuration, *Standard-Total*, five equipment items are included: *TW-TRAYED* (tower), *HE FIXED T-S* (condenser), *HT HORIZ-DRUM* (reflux accumulator), *CP CENTRIF* (reflux pump), and *RB U-TUBE* (reboiler). Note that the two *C* entries denote stream splitters[†]. For this example, a reboiler pump will be added, as discussed in the section on *Adding Equipment.* Furthermore, each equipment item has a specific type assigned by Aspen IPE that can be modified. To modify the equipment type, highlight the item to be modified. In this example, the kettle reboiler with U-tubes is replaced by a kettle reboiler with a floating head. To begin, the *RB U-TUBE* reboiler is deleted by highlighting it and pressing *Delete One Mapping*:

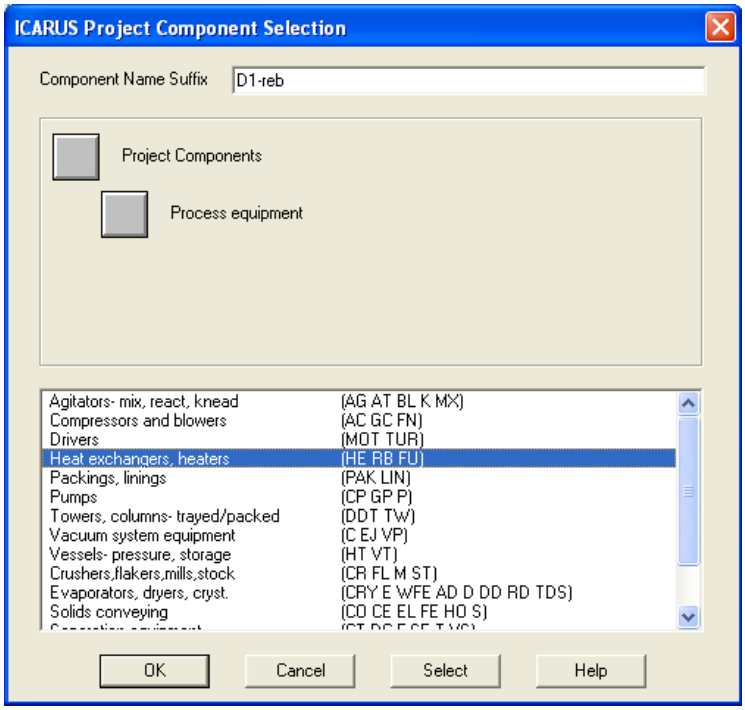


[†] When the configuration is switched from *Standard – Total* to *Full – Single*, a reboiler pump is automatically added during the mapping, as well as a distillation pump and two product heat exchangers. In this chapter, the reboiler pump is added manually for illustrative purposes.

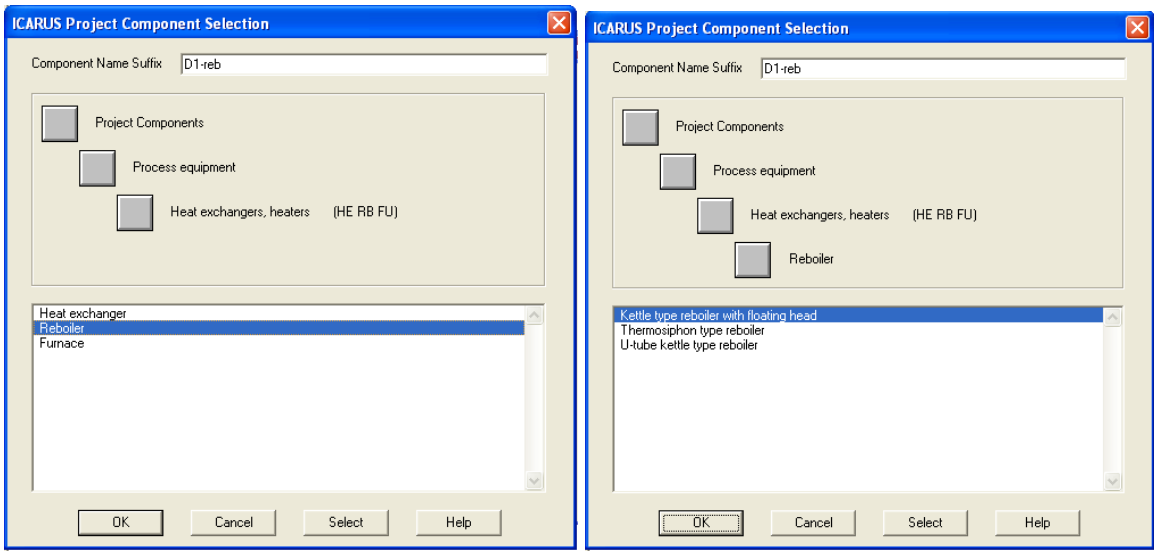
New Mapping is pressed and *reb* is highlighted on the screen that appears. Then, *OK* is pressed.



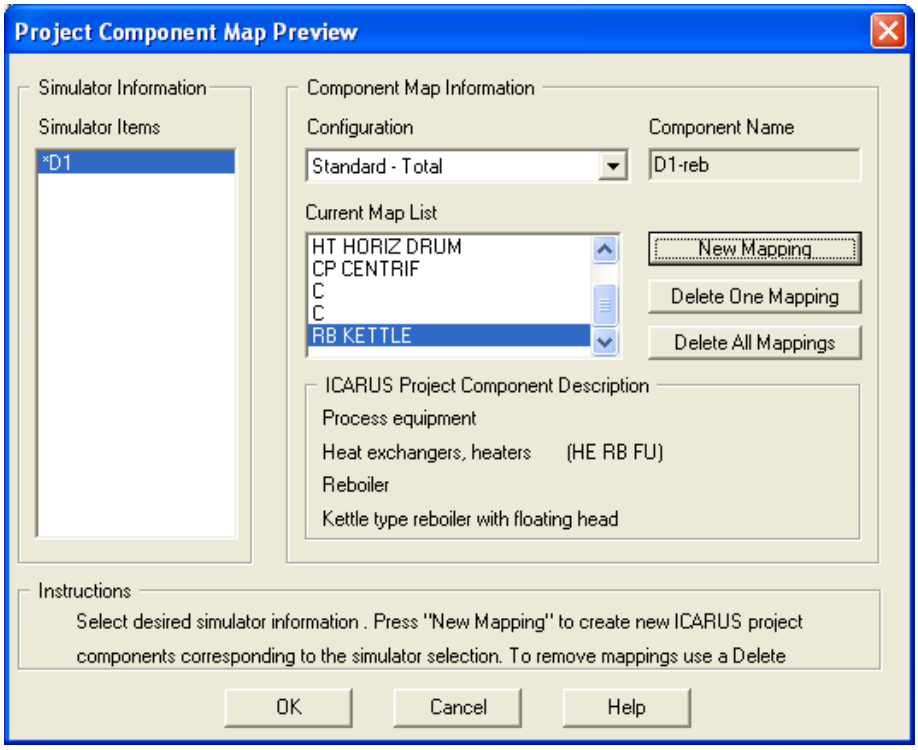
Next, *Heat Exchangers, heaters* is highlighted on the *ICARUS Project Component Selection* dialog box that appears, and *OK* is pressed.


ICARUS Project Component Selection
Component Name Suffix
D1-reb
Project Components
Process equipment
Agitators- mix, react, knead (AG AT BL K MX)
Compressors and blowers (AC GC FN)
Drivers (MOT TUR)
Heat exchangers, heaters (HE RB FU)
Packings, linings (PAK LIN)
Pumps (CP GP P)
Towers, columns- trayed/packed (DDT TW)
Vacuum system equipment (C EJ VP)
Vessels- pressure, storage (HT VT)
Crushers,flakers,mills,stock (CR FL M ST)
Evaporators, dryers, cryst. (CRY E WFE AD D DD RD TDS)
Solids conveying (CO CE EL FE HO S)
OK
Cancel
Select
Help

Reboiler is chosen from the dialog box that appears, and finally a *Kettle type reboiler with floating head* is selected as the last step of the replacement procedure.

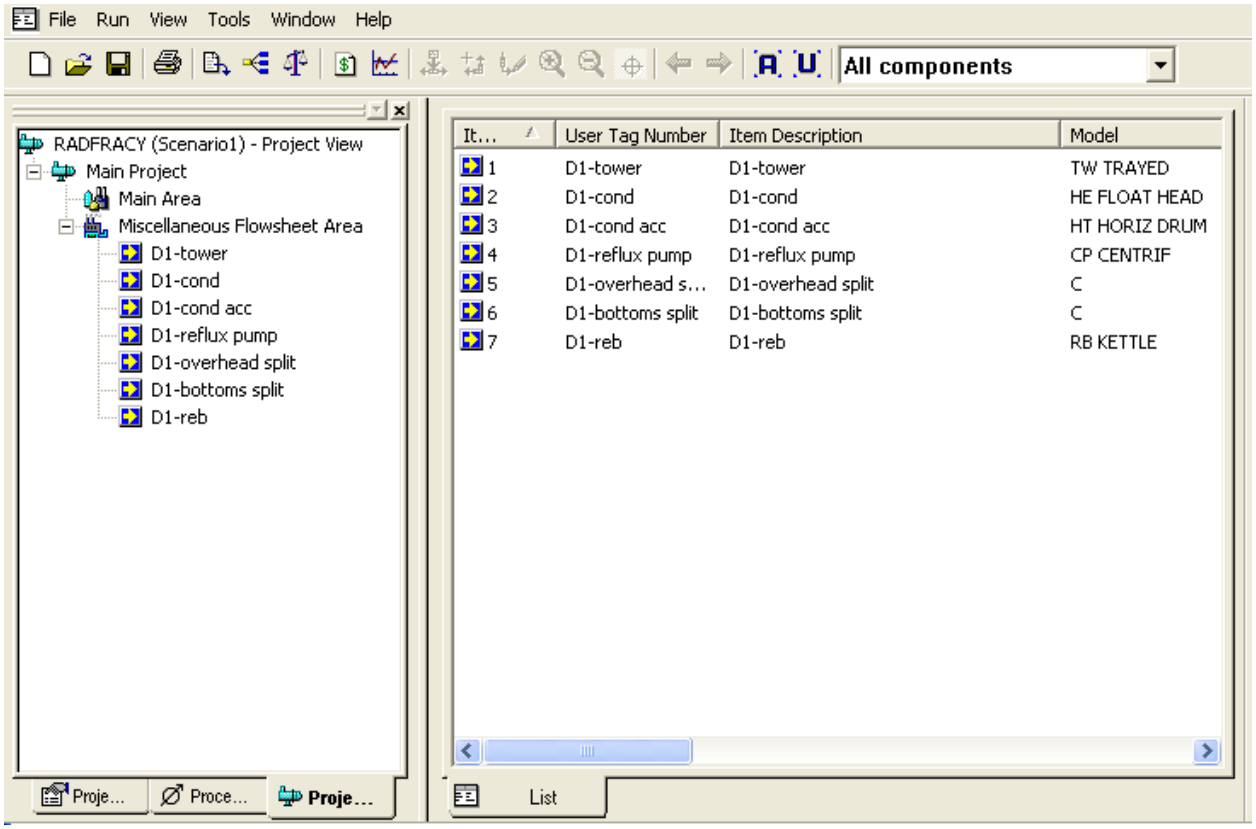


After these steps are completed, the modified mapping should appear on the *Project Component Map Preview* dialog box:



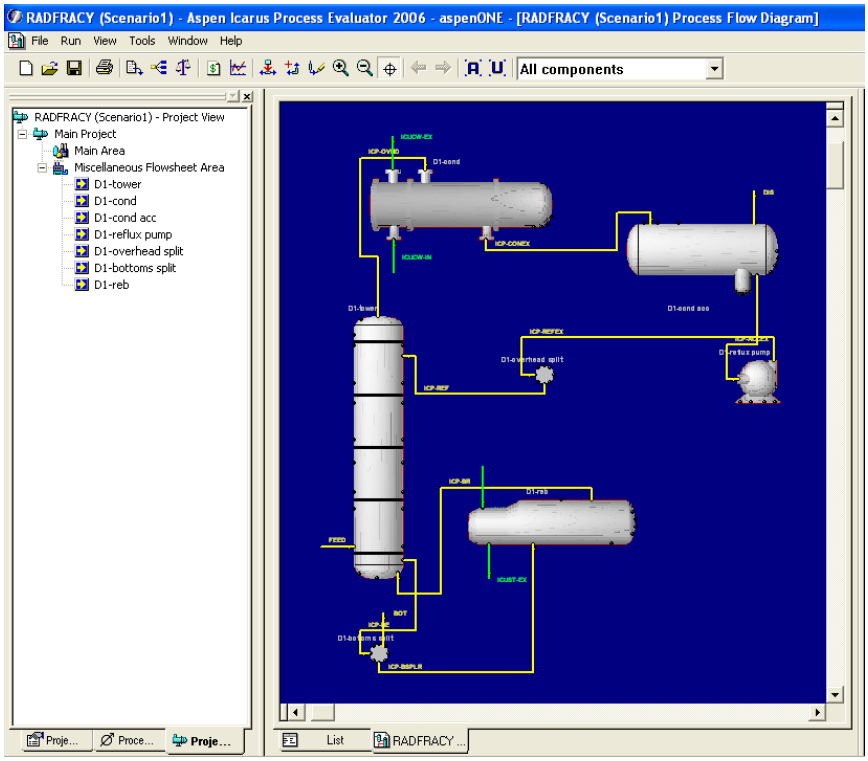
Other mappings can be altered in a similar fashion. For example, for the condenser, the mapping is altered from a shell-and-tube heat exchanger with a fixed tube sheet to one with a floating head. When the desired changes are completed, press *OK* to continue and wait for the equipment mapping and sizing to be completed.

At this point, the equipment items have been sized by Aspen IPE (because the *Size ICARUS Project Components* button was checked in the *Map* dialog box), whose calculations are based upon the simulator data, as well as the default values specified earlier. As each equipment item is sized, it appears in the Aspen IPE *Main* window as a list; that is, the *List* window. Note that the *Project Explorer* window displays the *Process View*:

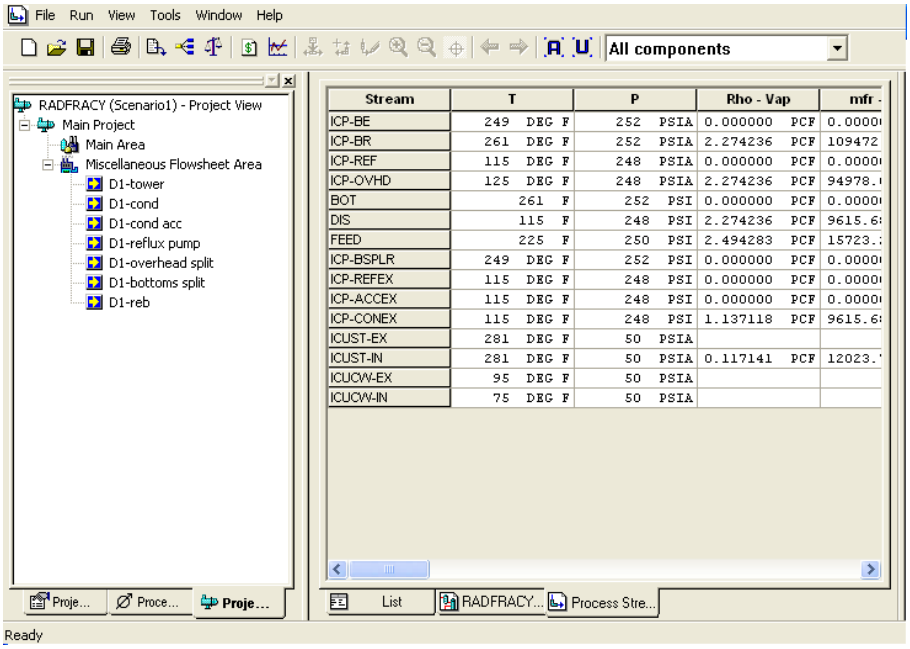


The blue boxes to the left of each item in the list indicate the *Project Components*. The yellow arrows inside the boxes indicate that the equipment item was obtained from the mapping of a process simulation unit, whose name appears after its box. Note that by default Aspen IPE lists all of the equipment items in the *Workbook Mode*, as shown above. The *List* tab at the bottom of the *Main* window denotes that the equipment items are listed in the *Workbook Mode*. Also note that user-inputted equipment items, such as a reboiler pump (not included in the above frame), are represented in the *Workbook* by blue boxes without the yellow arrow. To add these equipment items, see the section *Adding Equipment.* The *OK* in the *Status* column of the *Workbook* indicates that the minimum required information for costing the equipment is available. When one or more items are missing, a question mark appears instead, alerting the user to provide a specification(s) so that the equipment-sizing step can proceed.

In addition, it is possible to view the *IPE Process Flow Diagram.* This is accomplished using the *View* pulldown menu and clicking on *Process Flow Diagram* to produce:

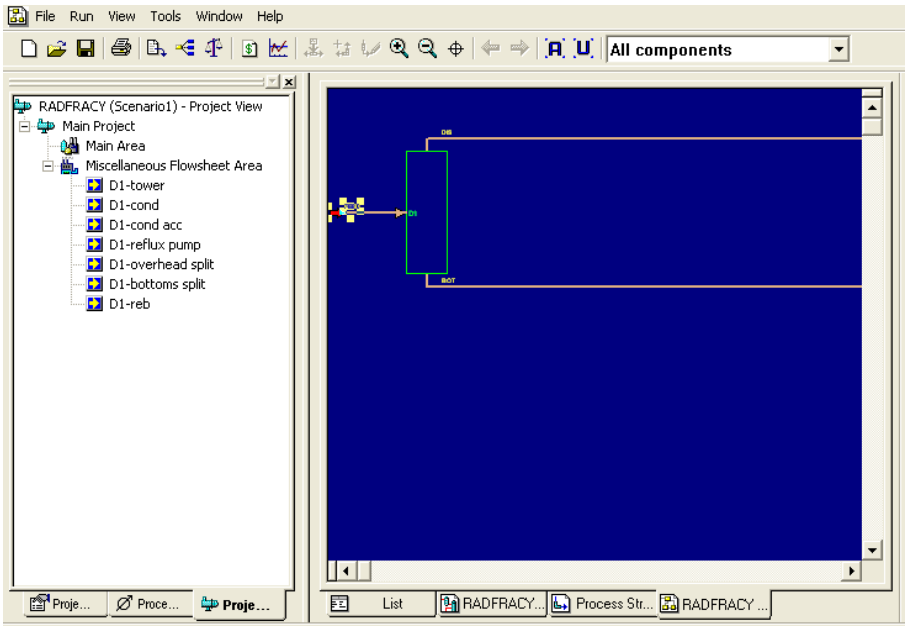


Note that the unit icons and streams have been repositioned using "drag and drop" facilities. It is also possible to view a list of the process streams utilized by Aspen IPE; that is, a list of all streams and their physical properties in the *Process Flow Diagram*. Using the *View* pulldown menu, click on *Streams List* to produce:

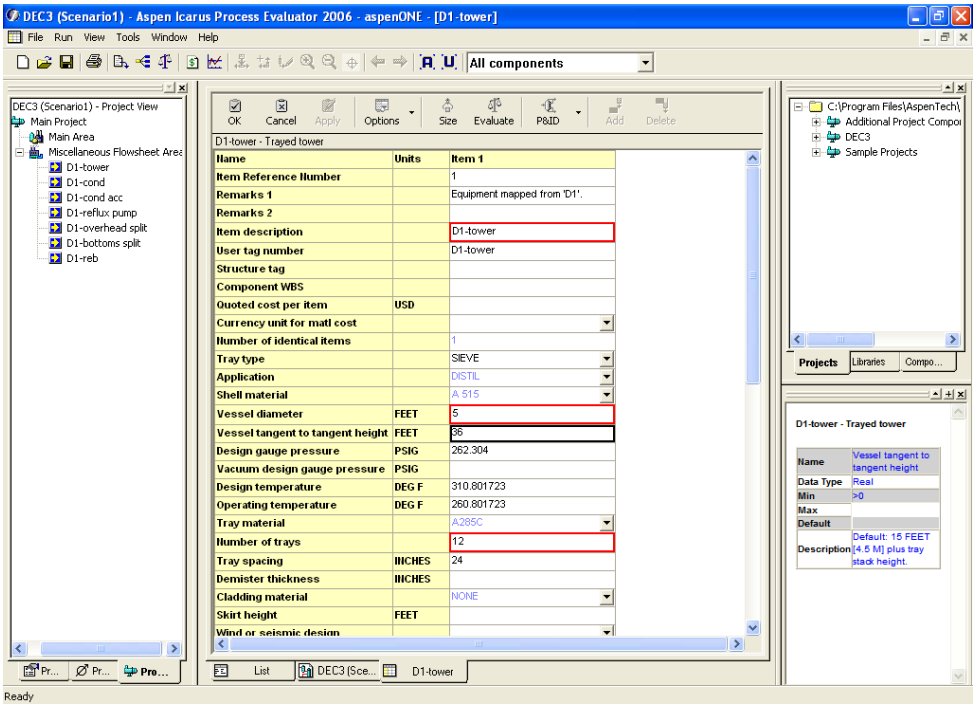


Stream	T	P	Rho - Vap	mfr
ICP-BE	249 DEG F	252 PSIA	0.000000 PCF	0.0000
ICP-BR	261 DEG F	252 PSIA	2.274236 PCF	109472
ICP-REF	115 DEG F	248 PSIA	0.000000 PCF	0.0000
ICP-OVHD	125 DEG F	248 PSIA	2.274236 PCF	94978.1
BOT	261 F	252 PSI	0.000000 PCF	0.0000
DIS	115 F	248 PSI	2.274236 PCF	9615.6
FEED	225 F	250 PSI	2.494283 PCF	15723.3
ICP-BSPLR	249 DEG F	252 PSI	0.000000 PCF	0.0000
ICP-REFEX	115 DEG F	248 PSI	0.000000 PCF	0.0000
ICP-ACCEX	115 DEG F	248 PSI	0.000000 PCF	0.0000
ICP-CONEX	115 DEG F	248 PSI	1.137118 PCF	9615.6
ICUST-EX	281 DEG F	50 PSIA		
ICUST-IN	281 DEG F	50 PSIA	0.117141 PCF	12023.7
ICUCW-EX	95 DEG F	50 PSIA		
ICUCW-IN	75 DEG F	50 PSIA		

Finally, the *IPE Block Flow Diagram* shows the simulation flowsheet. It is displayed using the *View* pulldown menu and clicking on *Block Flow Diagram* to give:



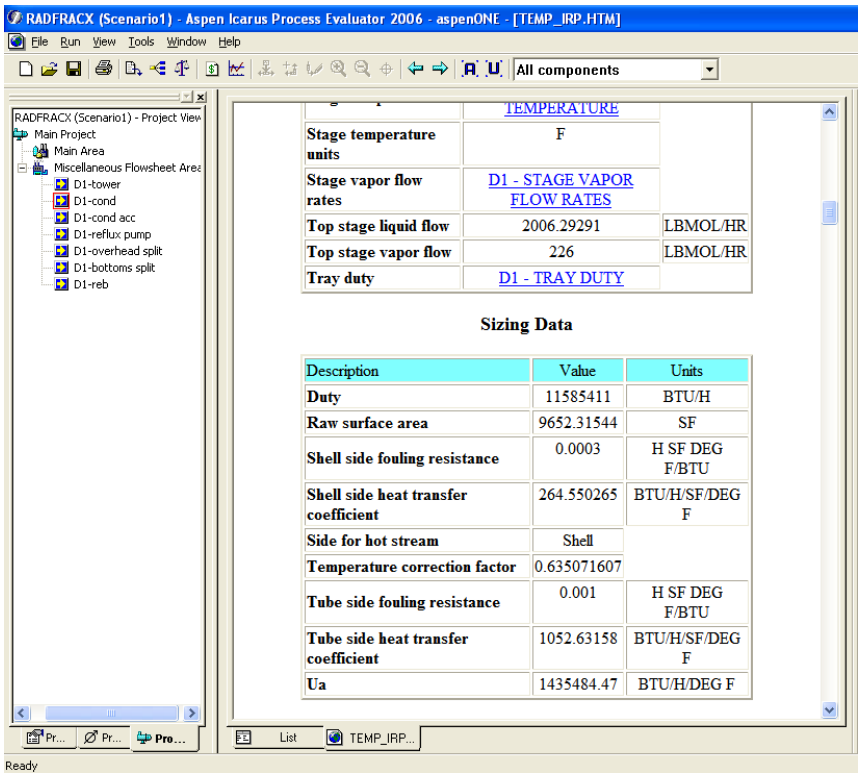
Mapping Results. After Aspen IPE has mapped and sized the equipment items, it is prudent to check the results, especially for major equipment items such as towers, compressors, and chemical reactors. These items are usually very expensive, and consequently, it is a good practice to estimate equipment sizes independently for comparison with the Aspen IPE results. To view the Aspen IPE results for an equipment item, double click on the item on the IPE *Workbook* window or on its icon in the *Process Flow Diagram*. For example, the following component specification form, which contains some of the sizing results, is obtained for the depropanizer tower.


DEC3 (Scenario1) - Aspen Icarus Process Evaluator 2006 - aspenONE - [D1-tower]
File Run View Tools Window Help
All components
OK Cancel Apply Options Size Evaluate P&ID Add Delete
D1-tower - Trayed tower
Name Units Item 1
Item Reference Number 1
Remarks 1 Equipment mapped from 'D1'.
Remarks 2
Item description D1-tower
User tag number D1-tower
Structure tag
Component WBS
Quoted cost per item USD
Currency unit for matl cost
Number of identical items 1
Tray type SIEVE
Application DISTIL
Shell material A 515
Vessel diameter FEET 5
Vessel tangent to tangent height FEET 36
Design gauge pressure PSIG 262.304
Vacuum design gauge pressure PSIG
Design temperature DEG F 310.801723
Operating temperature DEG F 260.801723
Tray material A285C
Number of trays 12
Tray spacing INCHES 24
Demister thickness INCHES
Cladding material NONE
Skirt height FEET
Wind or seismic design
Projects Libraries
Name Vessel tangent to tangent height
Data Type Real
Min >0
Max
Default
Description Default: 15 FEET [4.5 M] plus tray stack height.
Ready

Observe that the depropanizer tower was designed by Aspen IPE to have a 5 ft diameter and a 36 ft (tangent-to-tangent) height using sieve trays. Note that the number of trays is the number of equilibrium stages (12 = 14 – 2, excluding the condenser and reboiler) divided by the tray efficiency (0.8), which is 12/0.8 = 15. With a 2-ft tray spacing, a 4-ft high disengagement region at the top and a 10-ft high sump at the bottom, the nominal vessel tangent-to-tangent height is $2 \times 14 + 4 + 10 = 42$ ft. Consequently, the number of trays and the vessel tangent-to-tangent height must be adjusted manually to 15 and 42 ft, respectively. Be sure to click the OK button at the top of the form to save any sizing changes. Also, Aspen IPE calculated a design temperature and pressure in accordance with the *Design Criteria* specifications, used the default shell material, A515 (which is carbon steel for pressure vessels at intermediate and higher temperatures), and used the default tray material, A285C (which is for carbon steel plates in pressure vessels that have low and intermediate strength). Material codes, alloy types, and maximum service temperatures are tabulated in the chapter on *Material Selections* in the *ICARUS Reference Manual* (choose the *Documentation* option in the *Help* menu in Aspen IPE and follow the link for *Icarus Reference*). Furthermore, the effect of material on size and cost can be determined easily. In some cases, a high-strength alloy, that is more expensive per pound, may have thinner walls and be less expensive than a low-strength material that is less expensive per pound.

Changes can be made to any of the equipment sizes computed by Aspen IPE or to the default values used by Aspen IPE. Note that the default values are displayed in blue. As changes are made, dependent results are adjusted by Aspen IPE.

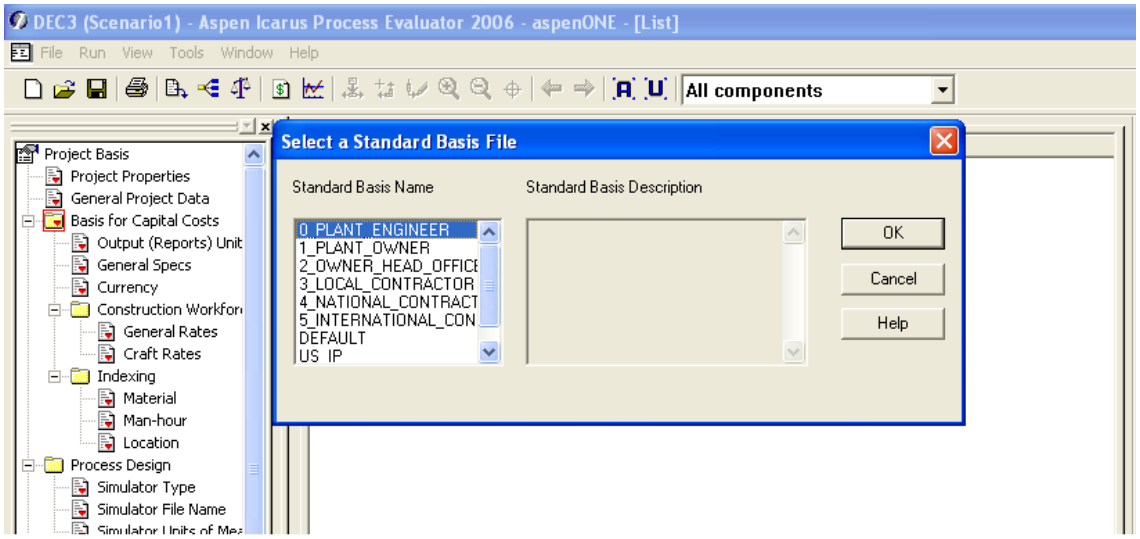
A more detailed report can be obtained in two ways. First, right click on the equipment item in the *Process Flow Diagram* and select *Item Report* in the menu that appears. Alternatively, right click on the equipment item in the *Project View* of the *Project Explorer* in the *Main* window (or in the *List View*) and select *Item Report* in the menu that appears. These steps produce the *Item Report*, a portion of which is illustrated here for the condenser:


RADFRACX (Scenario1) - Aspen Icarus Process Evaluator 2006 - aspenONE - [TEMP_IRP.HTM]
File Run View Tools Window Help
All components
RADFRACX (Scenario1) - Project View
Main Project
Main Area
Miscellaneous Flowsheet Area
D1-tower
D1-cond
D1-cond acc
D1-reflux pump
D1-overhead split
D1-bottoms split
D1-reb
TEMPERATURE
Stage temperature units F
Stage vapor flow rates D1 - STAGE VAPOR FLOW RATES
Top stage liquid flow 2006.29291 LBMOL/HR
Top stage vapor flow 226 LBMOL/HR
Tray duty D1 - TRAY DUTY
Sizing Data
Description Value Units
Duty 11585411 BTU/H
Raw surface area 9652.31544 SF
Shell side fouling resistance 0.0003 H SF DEG F/BTU
Shell side heat transfer coefficient 264.550265 BTU/H/SF/DEG F
Side for hot stream Shell
Temperature correction factor 0.635071607
Tube side fouling resistance 0.001 H SF DEG F/BTU
Tube side heat transfer coefficient 1052.63158 BTU/H/SF/DEG F
Ua 1435484.47 BTU/H/DEG F
List
TEMP_IRP...
Ready

Note that only a small portion of the *Item Report* is shown above. The raw surface area, 9,652 ft^2, is quite large because the log-mean temperature difference, 12.7°F (not shown above), is relatively small. This is related to the condenser pressure which was set at 248 psia. At this pressure, the distillate enters the condenser at 125°F and leaves as a saturated vapor at 115°F. Using cooling water heated from 90 to 120°F, the small log-mean temperature difference is obtained. It might be preferable to increase the column pressure to increase the log-mean temperature difference and reduce the condenser area. However, at a higher pressure the separation would become somewhat more difficult, resulting in more trays. Note that Aspen IPE can easily compare the capital costs at various pressures. Note also that Aspen IPE used two floating-head, shell-and-tube heat exchanger in parallel for condensing the overhead vapor. Each condenser has two tube passes with a temperature correction factor [F_T in Eq. (18.7)] of 0.635. The number of tube and shell passes for each exchanger can be seen on the report produced by double clicking on the condenser in the IPE *Workbook* window or on the condenser icon in the *Process Flow Diagram*. It might be possible to improve the condenser design by re-sizing the unit with different numbers of shell and tube passes to give a correction factor close to unity.

Standard Basis

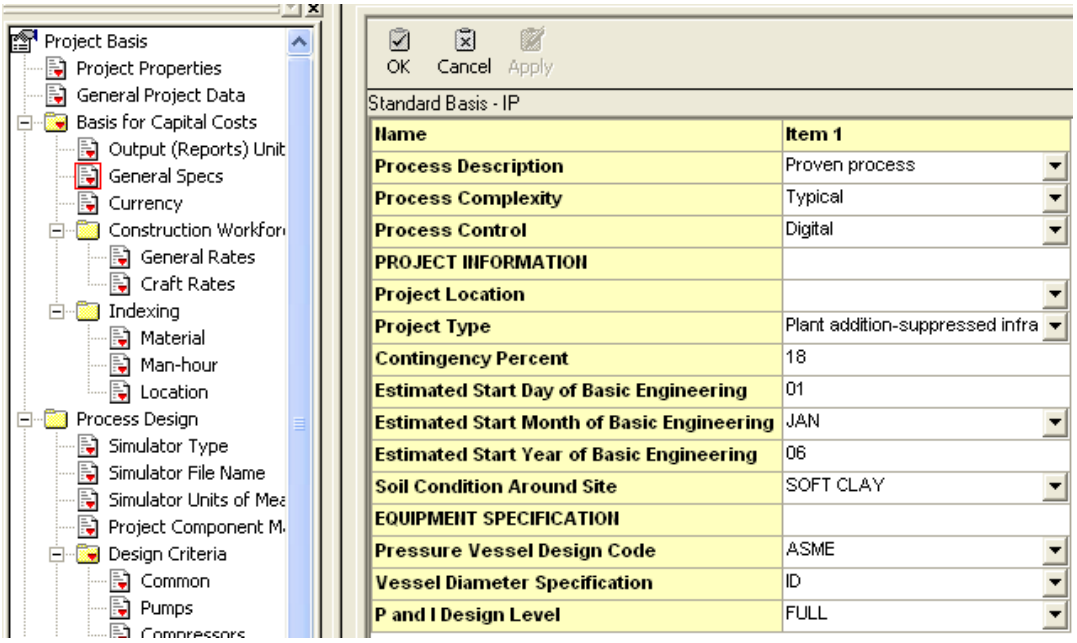
Six standard basis profiles are available within Aspen IPE for estimating the capital cost. These model the nature of the contractor to execute the project, depending on the size of the project, as shown below. Three of the profiles are for projects to be executed by an *Owner* company (0, 1, and 2), and the other three are for projects to be executed by *Engineering and Construction* firms (3, 4, and 5). For the small depropanizer project of this example, the *LOCAL CONTRACTOR* is appropriate.



To select a standard basis profile for a project, in the *Project Basis* view, right-click on the *Basis for Capital Costs*. Click *Select* to choose the most appropriate profile. You may be asked to confirm your selection since your choice may alter costs that have been previously determined.

The *Basis for Capital Costs* includes specifications for process controls, plant location, currency, wage rates, units of measure, and contractor profiles. Default values are provided for all entries, most of which need not be adjusted.

When modifying the *Basis for Capital Costs*, changes can be made to the *General Standard Basis Specifications* or to the *Construction Workforce* and *Indexing*. To view the *General Standard Basis Specifications*, the *Project Basis* tab is selected in the *Project Explorer*. Double-click the *General Specs* entry under the *Basis for Capital Costs* heading to produce the *Standard Basis-IP* dialog box:



For the depropanizer column, most of the default values are acceptable. Because a single distillation system would be installed normally on an existing plant site, using utilities provided by the site, the *Project Type* would not be selected as *Grass Roots/Clear field*. This *Project Type* would cause new items, already provided at the site, to be included in the design and cost estimates. Typically, these include a new control system and electrical substation components.

Under *Project Type*, click on the *Value* field to produce a pulldown menu that displays the options:

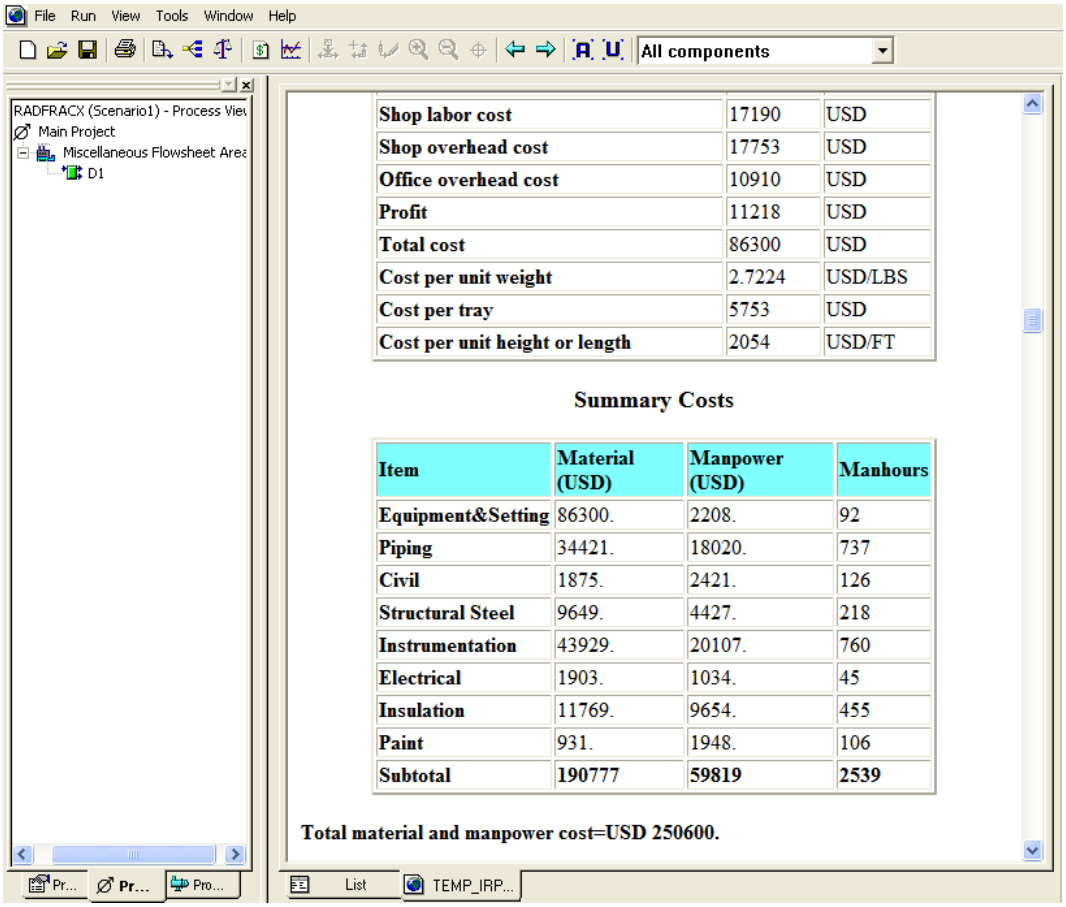
Grass Roots/Clear field
Plant addition – adjacent to existing plant
Plant additions – inside existing plant
Plant addition – suppressed infrastructure
Plant modification/Revamp

While guidelines are not provided concerning the selection of *Project Type*, costs can be computed for each option, if desired. Through examination of the results, the default values and items included or omitted can be observed. When selecting *Plant addition – suppressed infrastructure*, items involving the new control system, electrical switchgear, and transformers, are not provided. These are not needed for the addition of the depropanizer column to an existing process.

Note that in some older versions of Aspen IPE, the *Estimated Start Day of Engineering* (or *Month* or *Year*) may have a null default value in the *General Specs* form. Unless a finite value is entered, an error message results when the process units are evaluated; that is, when purchase and installation costs are estimated.

Equipment Costing

Aspen IPE estimates the purchase and installed cost of each equipment item individually or provides estimates for all of the equipment items (i.e., the entire project) using a single command. For an individual unit, right click on the unit in the *List View* and select *Evaluate Item.* Aspen IPE produces a detailed item report for the unit. For the depropanizer tower, by scrolling about a third of the way down the report, the following summary of the cost estimates appears:


File Run View Tools Window Help
All components
RADFRACX (Scenario1) - Process Vie
Main Project
Miscellaneous Flowsheet Area
D1
Shop labor cost 17190 USD
Shop overhead cost 17753 USD
Office overhead cost 10910 USD
Profit 11218 USD
Total cost 86300 USD
Cost per unit weight 2.7224 USD/LBS
Cost per tray 5753 USD
Cost per unit height or length 2054 USD/FT
Summary Costs
Item | Material (USD) | Manpower (USD) | Manhours
Equipment&Setting | 86300. | 2208. | 92
Piping | 34421. | 18020. | 737
Civil | 1875. | 2421. | 126
Structural Steel | 9649. | 4427. | 218
Instrumentation | 43929. | 20107. | 760
Electrical | 1903. | 1034. | 45
Insulation | 11769. | 9654. | 455
Paint | 931. | 1948. | 106
Subtotal | 190777 | 59819 | 2539
Total material and manpower cost=USD 250600.
List
TEMP_IRP...

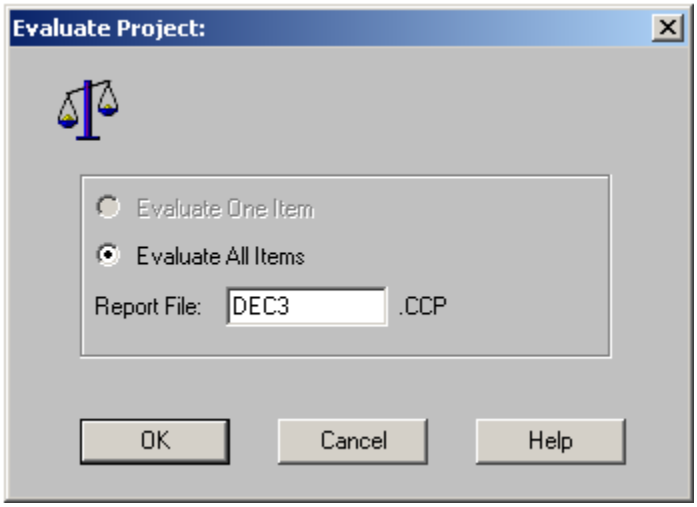
Observe that the tower designed by Aspen IPE has a *Purchased (Equipment and Setting) Cost* of $86,300 and an *Installed Direct Cost* of $250,600, which includes the cost of the tower and setting it in place on its foundation (civil). At this point, the designer can observe the effects of modifications in the design specifications on these costs for the unit. Be aware that the *Total Material and Manpower Cost* is the cost of the equipment item and the direct cost of installation materials and labor (directly related to the equipment item). These include the piping and field instruments that bring the process streams to and from the tower; the foundation to support the tower, structural steel (e.g., ladders and platforms attached to the tower); electrical lighting, heat tracing, cable, and local components; insulation; piping; and fireproofing. It does not include: (1) the fractional cost of buildings, pipe racks, the project control system or electrical substations, fire control systems, chemical and storm sewers and drains, treatment

systems, fences, guard houses, etc.; (2) the work required to perform basic and detail engineering, to procure all project components, and to manage the engineering process; and (3) taxes, freight to the site, permits, royalties, etc.

Note that the cost basis date is \$2006Q1, with the costs updated in each new version of Aspen IPE. You can check the cost basis for your version by selecting *Show Cost Basis* in the *Help* menu.

Consequently, the total material and manpower cost is *not* the total bare module cost discussed in Section 22.3 of the textbook. The estimate reported by Aspen IPE does not include contractor engineering costs, indirect costs, cost of pipe racks and intra-plant piping, and the cost of sumps and sewers, which can be added to the project as additional items. Furthermore, because the report focuses on an equipment item and its associated installation items and costs, materials and manpower items not typically charged to the tower (e.g., charges for instrument testing, pipe testing, and equipment grounding) are excluded. These costs are accumulated for each area that contains project components and are summed for the entire project, as discussed later in this section.

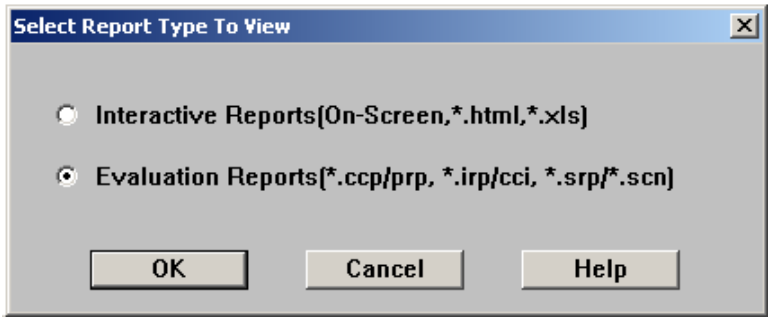
To have Aspen IPE estimate the capital costs of all the units at once (i.e., the entire project), press the *Evaluate Project* button on the IPE *Main* window. The *Evaluate Project* dialog box appears. The dialog box shows the default report file name, CAP_REP.CCP. The contents of this report are viewed in the *ICARUS Editor*. If you prefer a different name, e.g., DEC3 as shown below, enter it in the *Report File* field.



When finished with its evaluation, Aspen IPE displays a window that contains an executive summary of its results. This window is not shown here. Note that when the user presses the *Tools* pulldown menu, selects *Options*, and then *View Spreadsheet in Excel*, Aspen IPE is activated to prepare several spreadsheets, including the *Equipment Summary*, *Utility Summary* (available in Version 12.1), *ProjSum*, *Executive Summary*, and *Run Summary* spreadsheets (available in older versions). For the details of these spreadsheets, see the *Aspen IPE User's Guide* (choose *Documentation* from the *Help*

Menu and follow the path *Aspen Icarus Process Evaluator User's Manual* → *Evaluating the Project* → *Reviewing Investment Analysis*).

To view a detailed report of the capital costs, access the *ICARUS Editor* by pressing the *Capital Costs* ($) button on the IPE *Main* window. On the *Select Report Type to View* dialog box, mark the *Evaluation Reports* checkbox and press the *OK* button. Note that when the *Interactive Reports* checkbox is pressed, the *Aspen ICARUS Reporter* dialog box is produced. This permits the user to select individual items to be examined rather than entire reports as discussed below.



The *ICARUS Editor* displays the report in two adjacent windows, with the major subject headings listed in the left-hand window. Most of this information, though necessary for obtaining accurate cost estimates, is far too detailed for most estimates during the conceptual design stage, and hence, is normally not printed by process engineers, for whom these course notes are intended. Of greatest interest to process engineers, is the information in the following two sections:

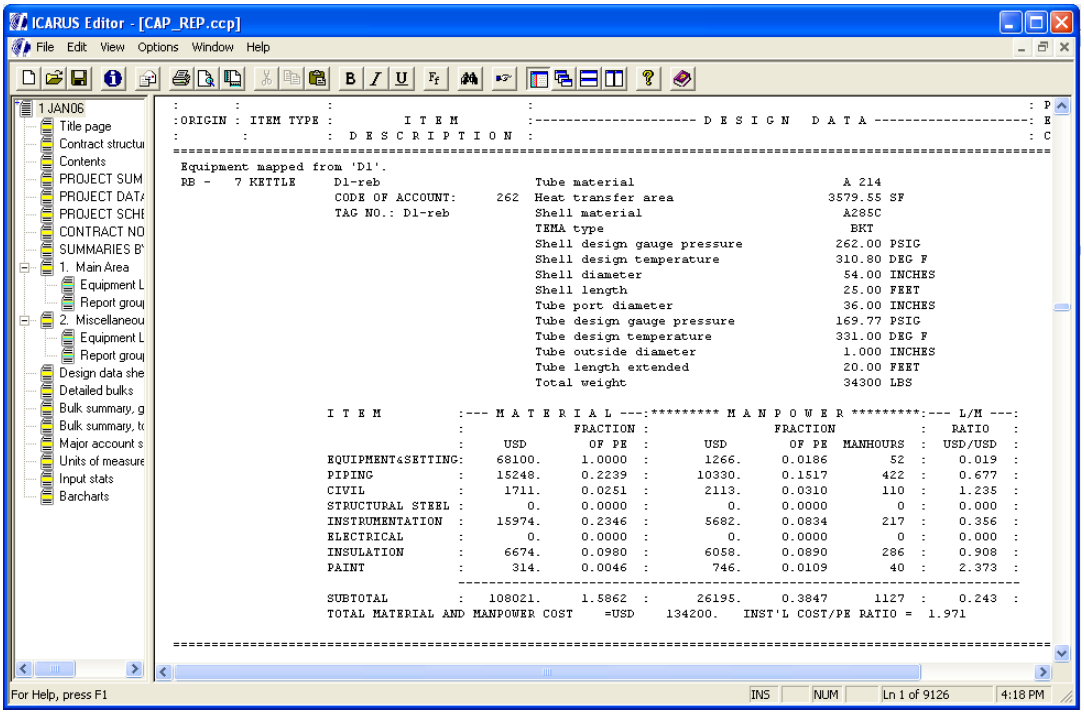
1. *Equipment List*
2. *CONTRACTOR NO. 1 PRIME CONTRACTOR*

which are accessed by double-clicking on these titles in the left-hand window. It is recommended that just small portions of the report be printed. This is accomplished by highlighting the desired section and pressing the *Print* button on the toolbar. It is often preferable to print in landscape format.

When the appropriate specifications are made, Aspen IPE computes annual operating costs, as well as a complete profitability analysis, the results of which appear in this *Investment Analysis* spreadsheet. These notes discuss capital cost estimation only because the spreadsheet, Profitability Analysis-2.0.xls, which is discussed in Section 23.8 of the textbook, is used to compute operating costs, working capital, and profitability measures.

As shown below, the *List of Equipment and Bulk Material by Area* portion of the report is displayed when the *Equipment List* is accessed. This provides the *Purchased (Equipment & Setting)* and *Installed Direct Costs* (i.e., *Total Material and Manpower Cost* or *Total Direct Materials and Labor Cost*) for each piece of equipment, e.g., the reboiler as shown next. Note that the right-hand window below is displayed using a 7-

point font. This is achieved by pressing the *Select Font* button on the toolbar. Furthermore, portions of the complete printed output are provided in Appendix III of these notes.


ICARUS Editor - [CAP_REP.ccp]
File Edit View Options Window Help
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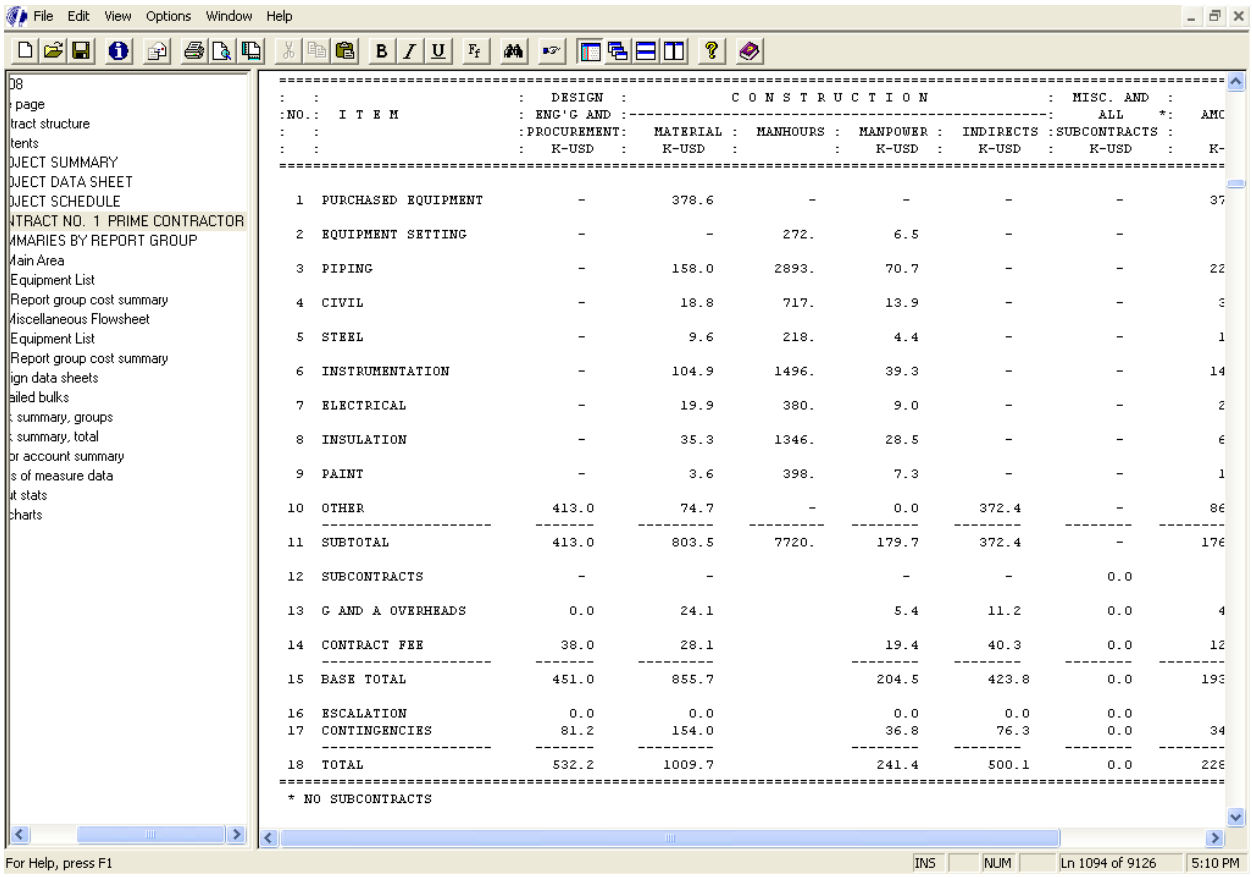
Contract structu
Contents
PROJECT SUM
PROJECT DATA
PROJECT SCHE
CONTRACT NO
SUMMARIES B
1. Main Area
Equipment L
Report grou
2. Miscellaneou
Equipment L
Report grou
Design data she
Detailed bulks
Bulk summary, g
Bulk summary, t
Major account s
Units of measure
Input stats
Barcharts
:ORIGIN : ITEM TYPE : I T E M : D E S I G N D A T A
: D E S C R I P T I O N :
Equipment mapped from 'D1'.
RB - 7 KETTLE D1-reb
CODE OF ACCOUNT: 262
TAG NO.: D1-reb
Tube material A 214
Heat transfer area 3579.55 SF
Shell material A285C
TEMA type BKT
Shell design gauge pressure 262.00 PSIG
Shell design temperature 310.80 DEG F
Shell diameter 54.00 INCHES
Shell length 25.00 FEET
Tube port diameter 36.00 INCHES
Tube design gauge pressure 169.77 PSIG
Tube design temperature 331.00 DEG F
Tube outside diameter 1.000 INCHES
Tube length extended 20.00 FEET
Total weight 34300 LBS
I T E M :--- M A T E R I A L ---:********* M A N P O W E R *********:--- L/M ---:
: FRACTION : FRACTION : RATIO :
: USD OF PE : USD OF PE MANHOURS : USD/USD :
EQUIPMENT&SETTING: 68100. 1.0000 : 1266. 0.0186 52 : 0.019 :
PIPING : 15248. 0.2239 : 10330. 0.1517 422 : 0.677 :
CIVIL : 1711. 0.0251 : 2113. 0.0310 110 : 1.235 :
STRUCTURAL STEEL : 0. 0.0000 : 0. 0.0000 0 : 0.000 :
INSTRUMENTATION : 15974. 0.2346 : 5682. 0.0834 217 : 0.356 :
ELECTRICAL : 0. 0.0000 : 0. 0.0000 0 : 0.000 :
INSULATION : 6674. 0.0980 : 6058. 0.0890 286 : 0.908 :
PAINT : 314. 0.0046 : 746. 0.0109 40 : 2.373 :
SUBTOTAL : 108021. 1.5862 : 26195. 0.3847 1127 : 0.243 :
TOTAL MATERIAL AND MANPOWER COST =USD 134200. INST'L COST/PE RATIO = 1.971
For Help, press F1
INS
NUM
Ln 1 of 9126
4:18 PM

In summary, the equipment sizes, purchase costs, and total material and manpower cost for the depropanizer system (without the reboiler pump) are as follows:

Simulation Unit	Equipment Item	Size	Purchase Cost	Total Material and Manpower Cost
D1	Tower	5.0 ft diam. 42 ft height	86,300	250,600
	Reflux pump	20 Hp	7,100	40,700
	Reboiler	3,580 ft^2	68,100	134,200
	Condenser	11,100 ft^2 5,550 ft^2/shell	179,800	326,100
	Reflux accumulator	2,350 gal	25,700	94,200
		TOTAL	$367,000	$845,800

The *Contract Summary* section of the *Capital Estimate Report* is displayed when the *CONTRACT NO. 1 PRIME CONTRACTOR* is accessed. The entries shown below are totals for all of the equipment items (i.e., the entire project)[†]. Note that selected portions of the complete printed output are provided in Appendix III of these notes.

[†] Note that changing to a 6- or 7-point font is more suitable for printing.



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JECT SUMMARY
JECT DATA SHEET
JECT SCHEDULE
NTRACT NO. 1 PRIME CONTRACTOR
MMARIES BY REPORT GROUP
Main Area
Equipment List
Report group cost summary
Miscellaneous Flowsheet
Equipment List
Report group cost summary
ign data sheets
ailed bulks
summary, groups
summary, total
or account summary
s of measure data
t stats
charts

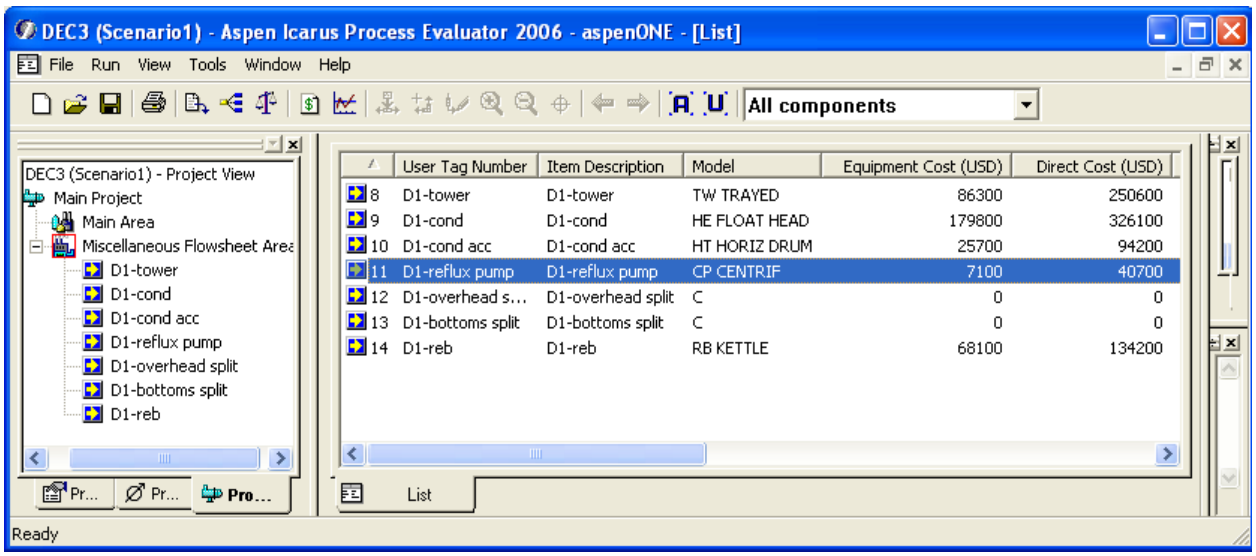
NO.	ITEM	DESIGN ENG'G AND PROCUREMENT K-USD	CONSTRUCTION MATERIAL K-USD	CONSTRUCTION MANHOURS	CONSTRUCTION MANPOWER K-USD	CONSTRUCTION INDIRECTS K-USD	MISC. AND ALL SUBCONTRACTS K-USD	AMC K-
1	PURCHASED EQUIPMENT	-	378.6	-	-	-	-	37
2	EQUIPMENT SETTING	-	-	272.	6.5	-	-	
3	PIPING	-	158.0	2893.	70.7	-	-	22
4	CIVIL	-	18.8	717.	13.9	-	-	3
5	STEEL	-	9.6	218.	4.4	-	-	1
6	INSTRUMENTATION	-	104.9	1496.	39.3	-	-	14
7	ELECTRICAL	-	19.9	380.	9.0	-	-	2
8	INSULATION	-	35.3	1346.	28.5	-	-	6
9	PAINT	-	3.6	398.	7.3	-	-	1
10	OTHER	413.0	74.7	-	0.0	372.4	-	86
11	SUBTOTAL	413.0	803.5	7720.	179.7	372.4	-	176
12	SUBCONTRACTS	-	-		-	-	0.0	
13	G AND A OVERHEADS	0.0	24.1		5.4	11.2	0.0	4
14	CONTRACT FEE	38.0	28.1		19.4	40.3	0.0	12
15	BASE TOTAL	451.0	855.7		204.5	423.8	0.0	193
16	ESCALATION	0.0	0.0		0.0	0.0	0.0	
17	CONTINGENCIES	81.2	154.0		36.8	76.3	0.0	34
18	TOTAL	532.2	1009.7		241.4	500.1	0.0	228

* NO SUBCONTRACTS

For Help, press F1 INS NUM Ln 1094 of 9126 5:10 PM

Note that the entry for the purchased equipment, $378,600, from line 1, is approximately the sum of the entries for the pieces of equipment provided above, $367,000. The difference is due to the *Misc. Item Allowance* ($11,100) and the *Warehouse Spares* ($500). These additional items are in *Code of Accounts* 105 and 107 and appear in the *Code of Accounts Summary* section of the *Capital Estimate Report* (just below the *Contract Summary*.)

The total direct material and manpower costs for construction of the plant are $803,500 and $179,700, as shown in line 11. These sum to $983,200 and include items that cannot be charged to the individual equipment items (e.g., charges for instrument testing, pipe testing, and equipment grounding). Note that the installed costs of the equipment items are displayed on the *List View*:


DEC3 (Scenario1) - Aspen Icarus Process Evaluator 2006 - aspenONE - [List]
File Run View Tools Window Help
All components
DEC3 (Scenario1) - Project View
Main Project
Main Area
Miscellaneous Flowsheet Area
D1-tower
D1-cond
D1-cond acc
D1-reflux pump
D1-overhead split
D1-bottoms split
D1-reb
User Tag Number | Item Description | Model | Equipment Cost (USD) | Direct Cost (USD)
8 D1-tower D1-tower TW TRAYED 86300 250600
9 D1-cond D1-cond HE FLOAT HEAD 179800 326100
10 D1-cond acc D1-cond acc HT HORIZ DRUM 25700 94200
11 D1-reflux pump D1-reflux pump CP CENTRIF 7100 40700
12 D1-overhead s... D1-overhead split C 0 0
13 D1-bottoms split D1-bottoms split C 0 0
14 D1-reb D1-reb RB KETTLE 68100 134200
List
Ready

The installed costs (shown in the Direct Cost column) sum to $845,800; that is, $137,400 less than the total direct cost of materials and manpower for installation of the plant, $983,200. This *Installed Direct Cost*, C_{DI}, is referred to in Chapter 22 of the textbook as the *Total Direct Materials and Labor Cost*, C_{DML}. Finally, the materials and manpower items that are not chargeable to the individual equipment items are displayed in the *Area Bulk Report* within the *Capital Estimate Report*:

A R E A B U L K R E P O R T

ORIGIN	ITEM SYMBOL	DESCRIPTION / DESIGN DATA		MATERIAL COST-USD	MANPOWER MANHOURS	MANPOWER COST-USD	TOTAL DIRECT COST-USD
AREA		MISC CONCRETE ITEMS		743.	140	2718.	3461.
AREA		PIPE TESTING		0.	204	5112.	5112.
GRADE		UNPAVED AREA		8552.	127	2997.	11549.
		Area length	50.000 FEET				
		Area width	50.000 FEET				
AREA		INSTRUMENT TESTING		0.	95	2474.	2474.
AREA		INSTR. RUNS,TRAYS,JBOX.		2200.	49	1150.	3350.
AREA		EQUIPMENT GROUNDING		209.	11	259.	468.
AREA		PILED FOUNDATION		10802.	83	1638.	12440.
		Number of piles	14				
AREA		ELECTRICAL TESTING		0.	16	389.	389.
AREA		ROTATING EQP SPARE PARTS		500.	0	0.	500.

These non-chargeable items add to $39,743. Together with the *Other* item on line 10 of the *Contract Summary*, $74,700, and *Code of Accounts* item 105, for equipment contingencies to allow for design changes, $11,100, these sum to approximately $125,543 (which is sufficiently close to $137,400 the difference reported above).

Returning to the *Capital Estimate Report*, material and manpower costs associated with *G and A (General and Administrative) Overheads*, $24,100 and $5,400, are obtained from line 13, and material and manpower charges associated with *Contract Fees*, $28,100 and $19,400, from line 14. These sum to $77,000. The contractor engineering and indirect costs are in row 15, *BASE TOTAL*, in the first column, under *DESIGN ENG'G AND PROCUREMENT K-USD*, and in the fifth column, under *CONSTRUCTION INDIRECTS K-USD*. These are:

Contractor Engineering Costs	$451,000
Indirect Costs	$423,800

Together with the fees for materials and manpower *G and A Overheads* and *Contract Fees*, these are added to the total direct installed equipment costs, C_{DI}, to give the *IBL Total Bare Module Cost*, C_{TBM}.

Finally, all of the Aspen IPE results can be reproduced using the DEC3 folder (in the ASPEN folder on the Wiley web site for this book) from within Aspen IPE.

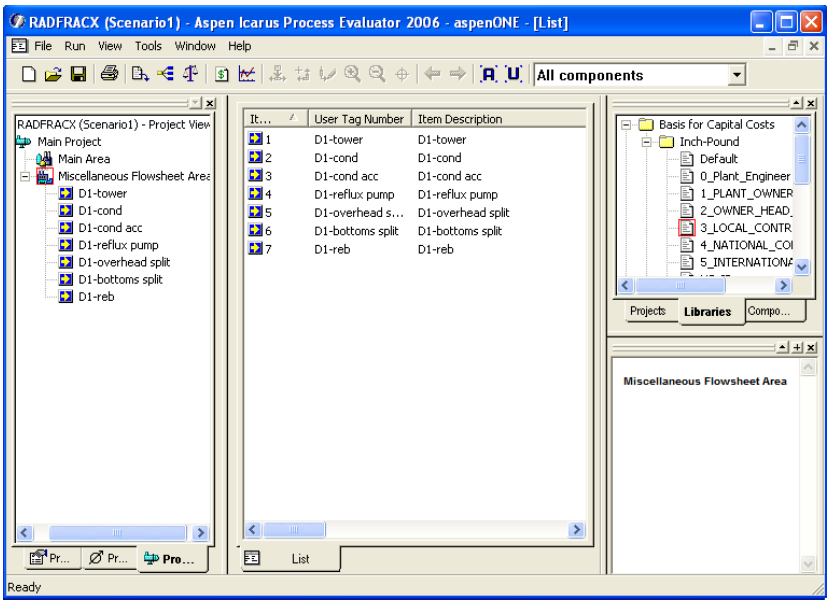
Total Permanent Investment

The total permanent investment is computed by the spreadsheet, Profitability Analysis-2.0.xls, discussed in Section 23.8 of the textbook. When using the Aspen IPE option, the user enters:

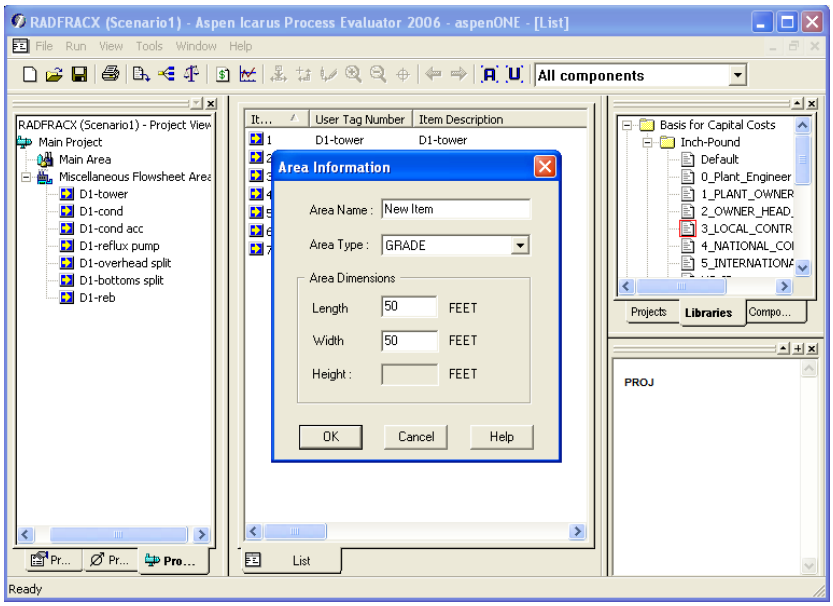
Total Direct Materials and Labor Costs	$983,200
Material and Labor G&A Overhead and Contractor Fees	77,000
Contractor Engineering Costs	451,000
Indirect Costs	423,800

Adding Equipment

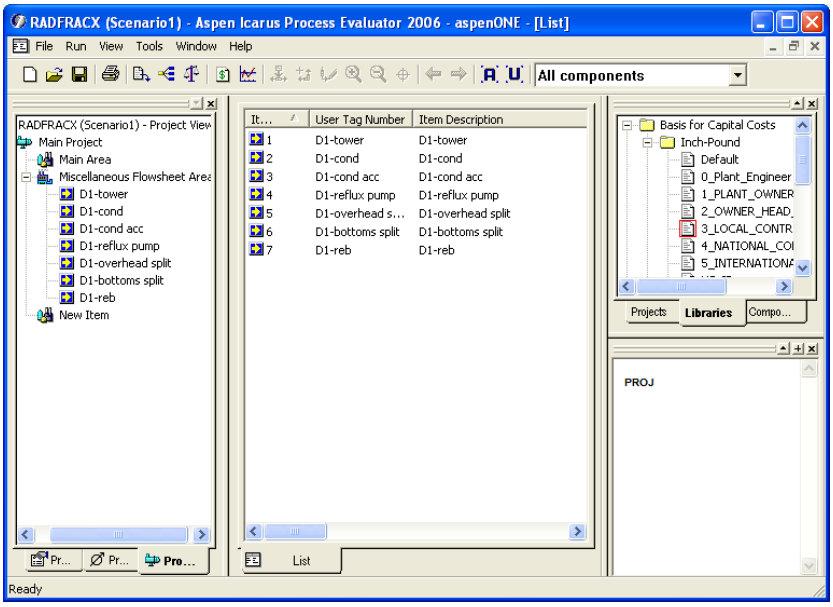
Thus far, all of the equipment items have originated with the simulation units from an ASPEN PLUS simulation. After the mappings have been completed, yellow arrows are placed in the blue boxes associated with each equipment item in the Aspen IPE *Main* window. Also, in the *Process Flow Diagram*, all of the streams are yellow, with the exception of the IPE-generated utility streams, which are green. When it is desirable to add a piece of equipment that is not in a simulation or has not been created during the mapping of simulation units by Aspen IPE, the following steps are taken. From the IPE *Main* window, press the *Project View* tab at the bottom of the left-hand window (i.e., the *Project Explorer* window) to give:



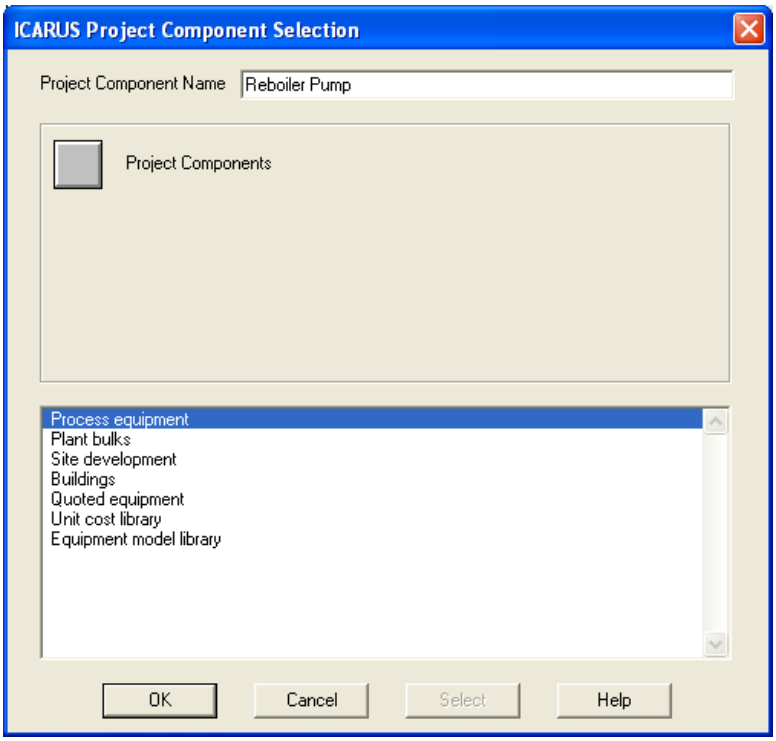
Then, highlight *Main Project*, right click, and press *Add Area* to produce the *Area Information* dialog box in which an *Area Name* (e.g., *New Item*) is entered with its dimensions. Here, a 50'x 50' area is reserved and used to estimate piping lengths, etc. This is adequate for most applications. Note that the original area for the plant, which was named *Miscellaneous Flowsheet Area* by Aspen IPE, is also 50' x 50' by default.



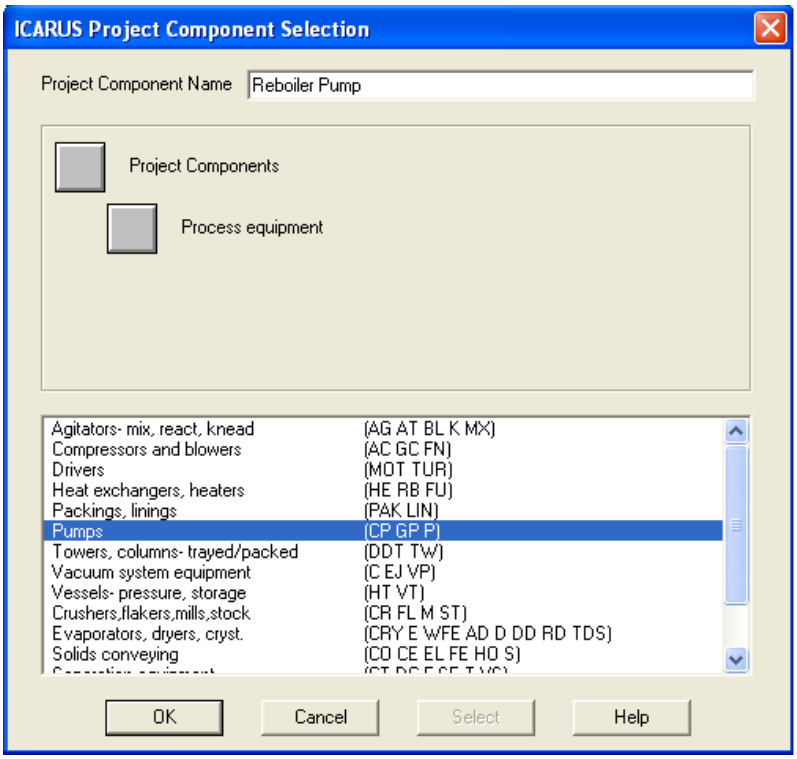
Press *OK* and the new area, which is named *New Item*, appears on the *Project View* (left window) of the IPE *Main* window.

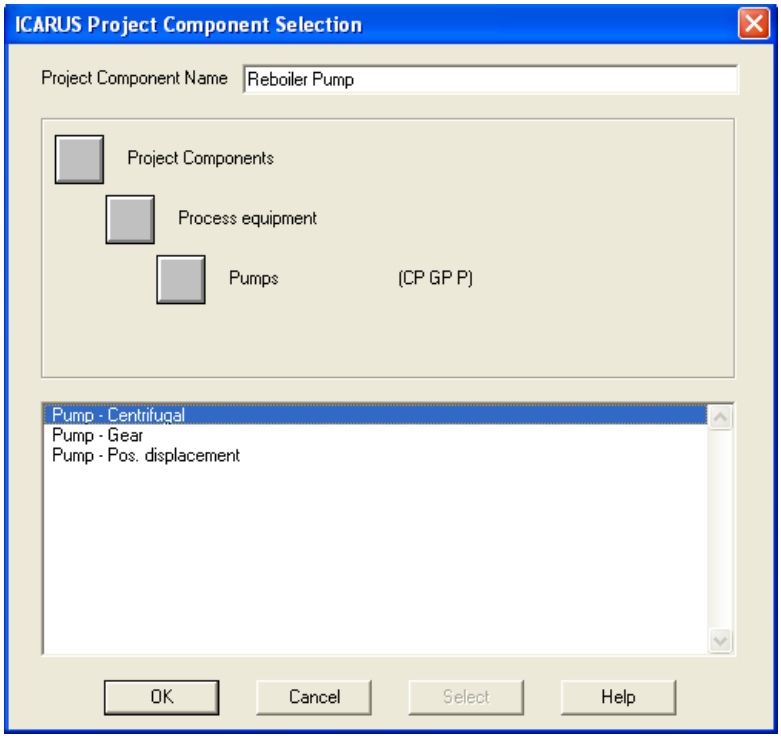


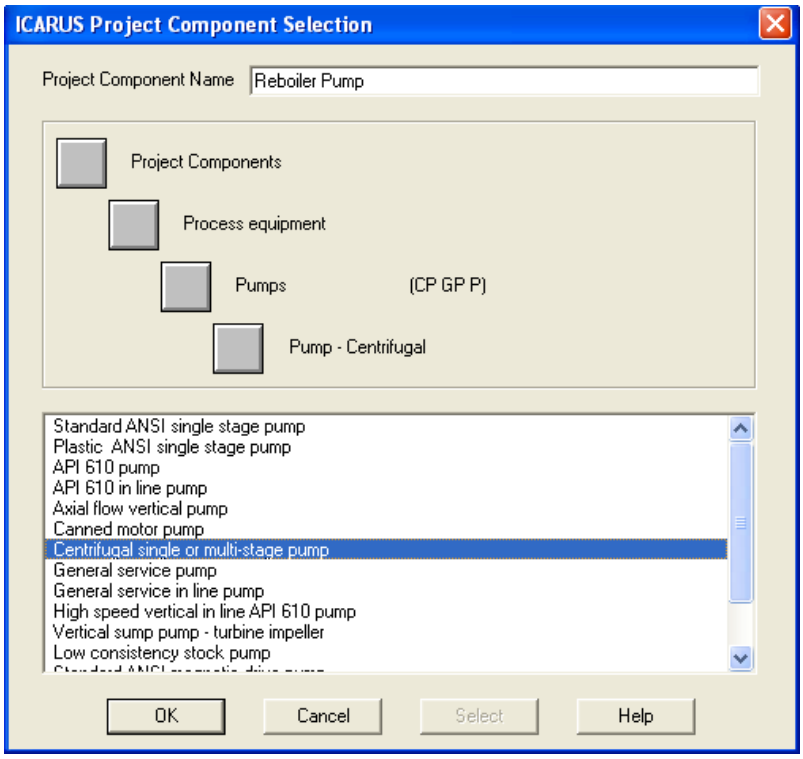
Next, highlight the *New Item* area, right click, and click on *Add Project Component* to produce the *ICARUS Project Component Selection* dialog box. For the addition of a reboiler pump, enter *Reboiler Pump* as the *Project Component Name*, highlight *Process equipment* and press the *OK* button.



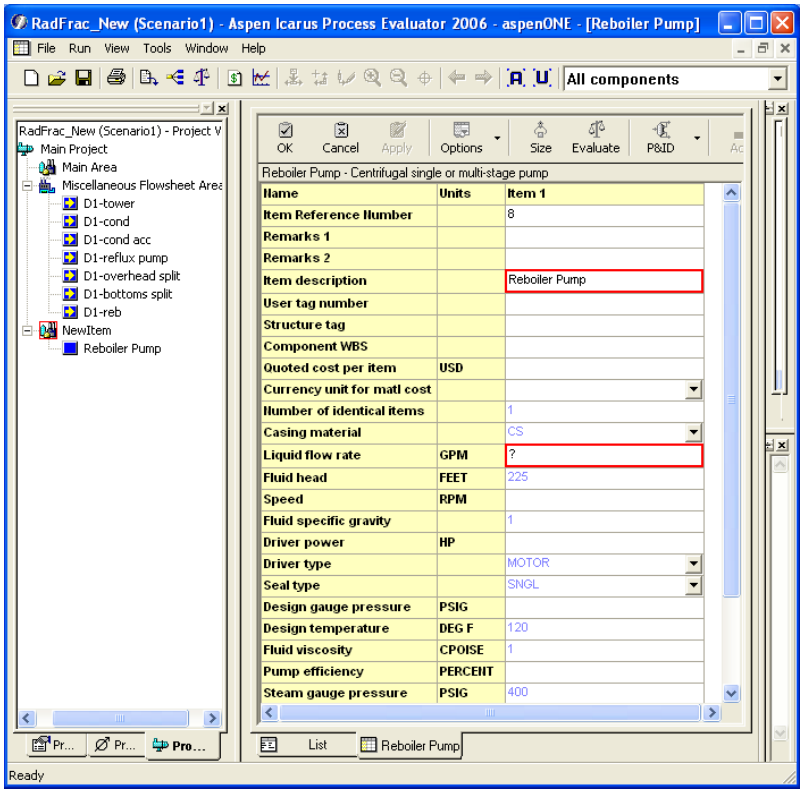
Continue through the appropriate menus until the desired equipment type is obtained, which in this example is a centrifugal pump.


ICARUS Project Component Selection
Project Component Name
Reboiler Pump
Project Components
Process equipment
Agitators- mix, react, knead (AG AT BL K MX)
Compressors and blowers (AC GC FN)
Drivers (MOT TUR)
Heat exchangers, heaters (HE RB FU)
Packings, linings (PAK LIN)
Pumps (CP GP P)
Towers, columns- trayed/packed (DDT TW)
Vacuum system equipment (C EJ VP)
Vessels- pressure, storage (HT VT)
Crushers,flakers,mills,stock (CR FL M ST)
Evaporators, dryers, cryst. (CRY E WFE AD D DD RD TDS)
Solids conveying (CO CE EL FE HO S)
OK
Cancel
Select
Help

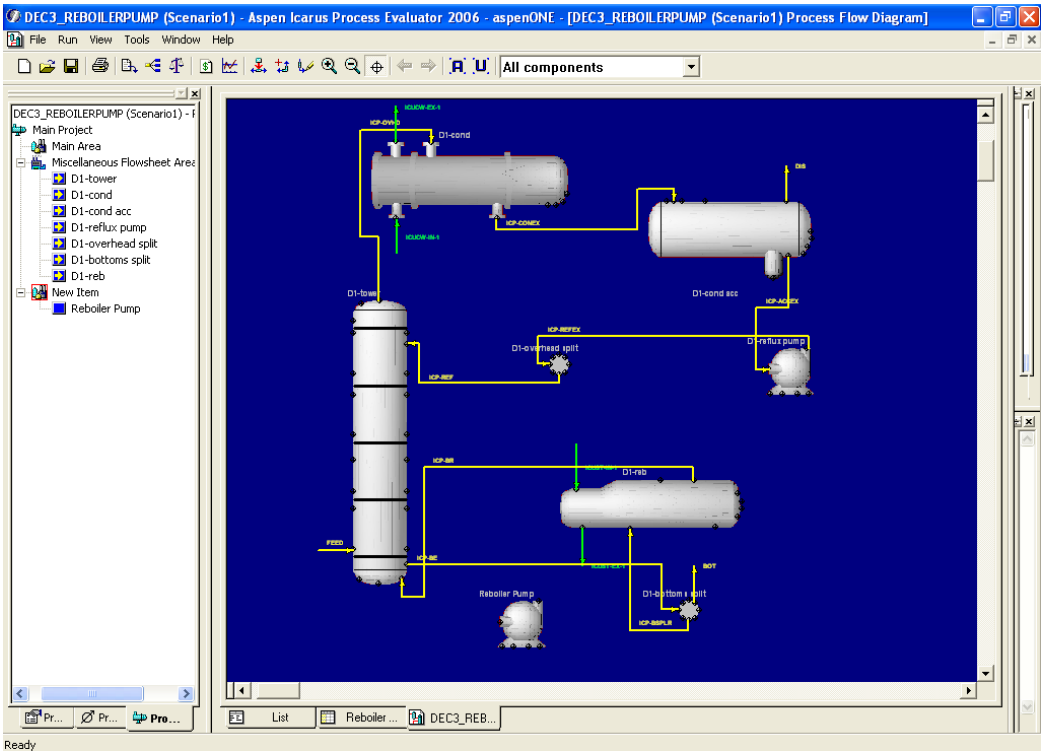

ICARUS Project Component Selection
Project Component Name
Reboiler Pump
Project Components
Process equipment
Pumps
(CP GP P)
Pump - Centrifugal
Pump - Gear
Pump - Pos. displacement
OK
Cancel
Select
Help



After the *OK* button is pressed, the pump specification form is displayed.



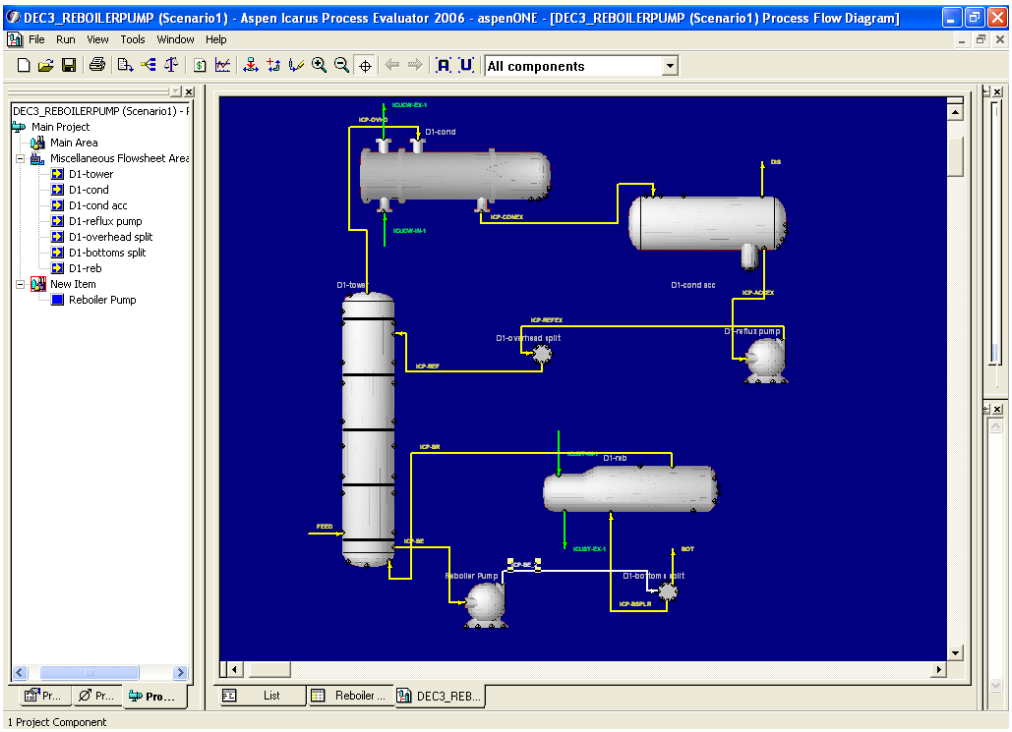
Note that the specifications are incomplete because the *Reboiler pump* has not been connected into the main process, which resides in the *Miscellaneous Flowsheet* Area, as shown in the IPE *Process Flow Diagram*:



The *Reboiler pump* is positioned in the upper-left-hand corner of the *Process Flow Diagram* in the *New Item* area, independent of the *Miscellaneous Flowsheet Area.* Observe that the *Reboiler pump* appears in the *New Item* area on the *Project View.*

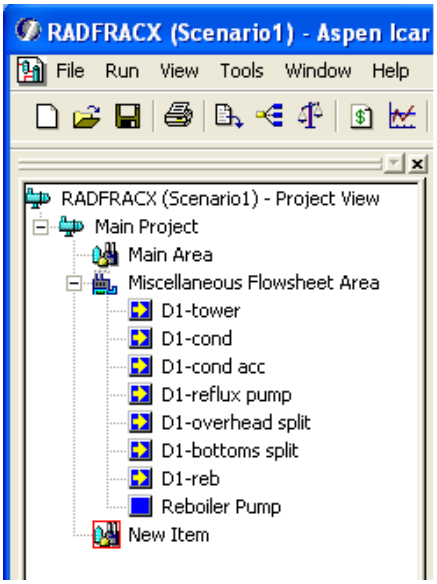
Before proceeding, after completing this example, it was brought to our attention that reboiler pumps are used normally with vertical reboilers, not with kettle reboilers. When appropriate to add a reboiler pump, or any other equipment item, to the mapping, the procedures in this section should be followed.

To insert the *Reboiler pump* into the liquid stream from the sump, *ICP-BE*, press the *Edit Connectivity* button and place the cursor over the *Reboiler pump*, after which the cursor becomes a hand. Keeping the left-mouse button depressed, drag the *Reboiler pump* over the *ICP-BE* stream. Release the mouse and click with the left-mouse button to insert the *Reboiler pump.* After the streams are realigned, the *Process Flow Diagram* appears as follows:

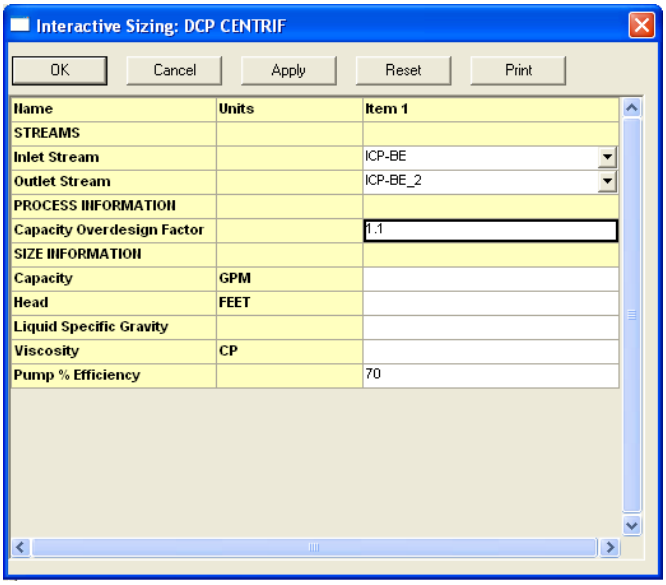


Note that a new stream, which appears in white, has been created and named *ICP-BE_2* by Aspen IPE.

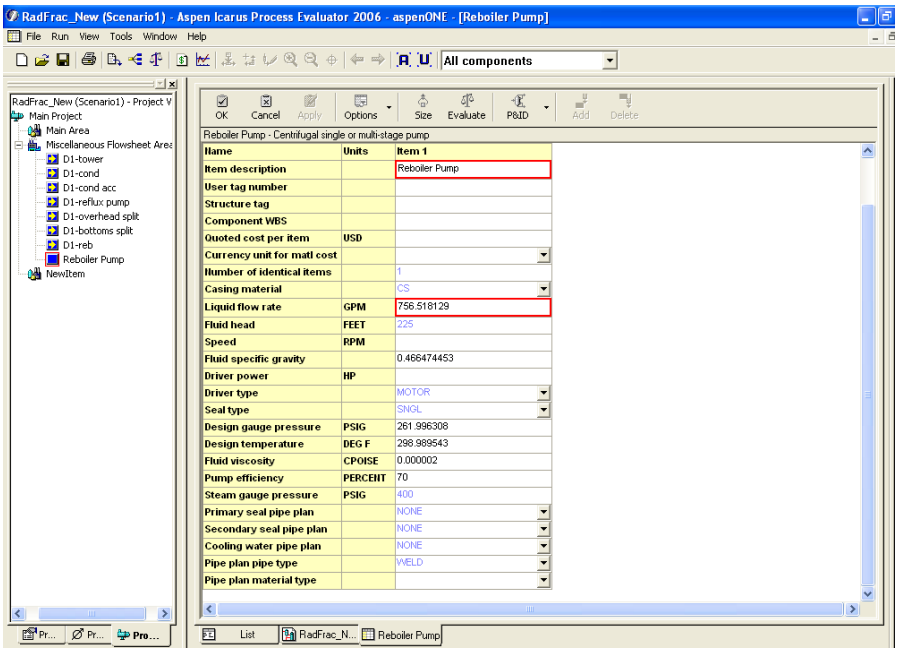
Although the *Reboiler pump* has been inserted into the process, it remains in the *New Item* area. To move it into the *Miscellaneous Flowsheet* area, in the *Project View*, drag and drop the *Reboiler pump* from the *New Item Area* to the *Miscellaneous Flowsheet* area. This results in:



Next, right click on the *Reboiler pump* and select *Size Item* on the menu that appears (note that the Spec Sheet for the reboiler pump may have to be closed first when it is open in another tab). The interactive sizing form appears:

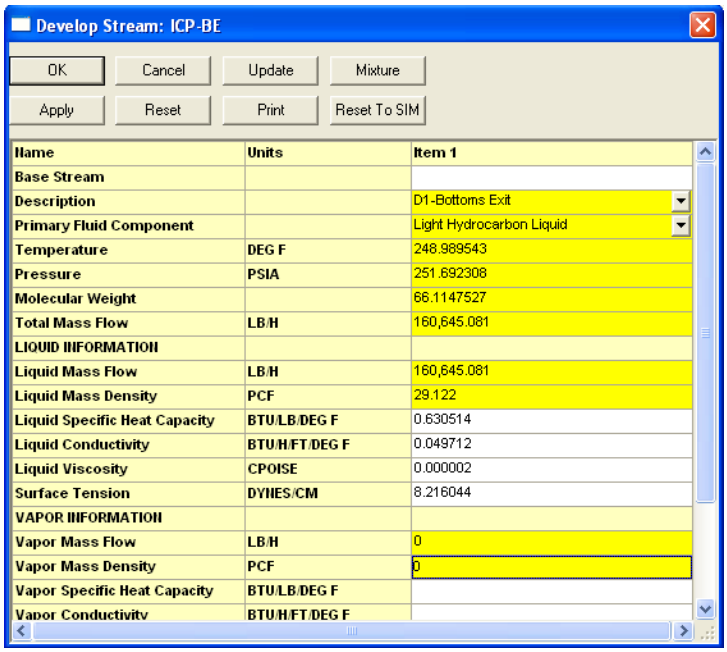


The blank fields for *Capacity*, *Head*, and *Pump % Efficiency* indicate that the pump has not been previously sized. When *OK* is pressed, Aspen IPE sizes the pump. When finished, double click on the pump icon to display the component specification form:



Note that the design capacity of the *Reboiler pump* has been adjusted to 756.5 gpm, which is 10 percent higher than the flow rate leaving the sump, a default specification in the *Design Criteria*. At this point, 20 ft is entered to replace the default fluid head of 225

ft; 20 ft should be sufficient to convey the bottoms liquid to the reboiler. Before leaving this form, click *OK*. To obtain the variables for the *ICP-BE* stream, double-click on it:

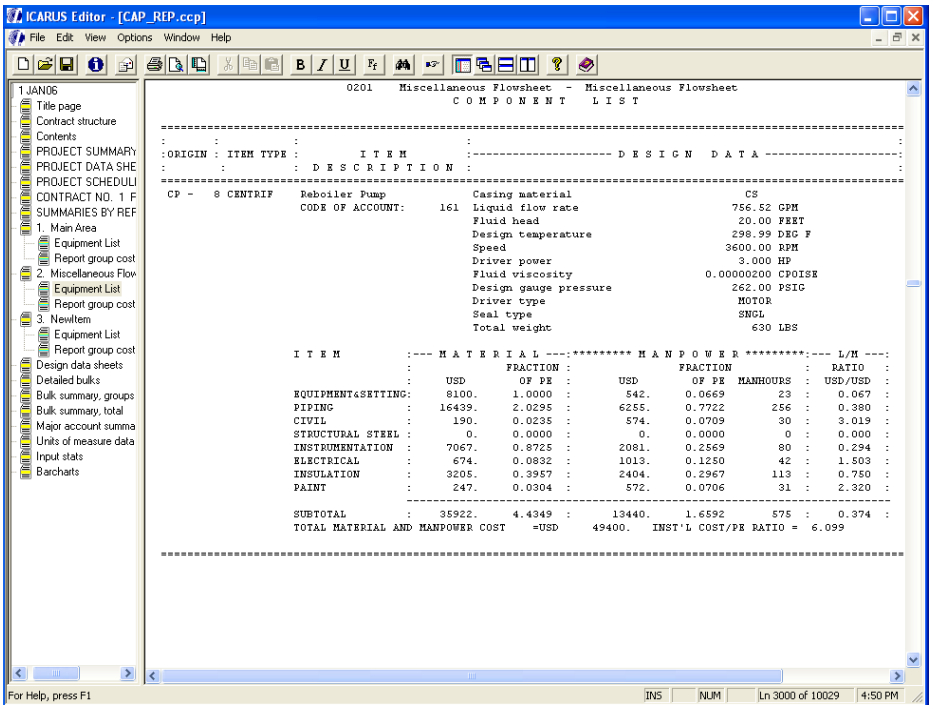


Name	Units	Item 1
Base Stream		
Description		D1-Bottoms Exit
Primary Fluid Component		Light Hydrocarbon Liquid
Temperature	DEG F	248.989543
Pressure	PSIA	251.692308
Molecular Weight		66.1147527
Total Mass Flow	LB/H	160,645.081
LIQUID INFORMATION		
Liquid Mass Flow	LB/H	160,645.081
Liquid Mass Density	PCF	29.122
Liquid Specific Heat Capacity	BTU/LB/DEG F	0.630514
Liquid Conductivity	BTU/H/FT/DEG F	0.049712
Liquid Viscosity	CPOISE	0.000002
Surface Tension	DYNES/CM	8.216044
VAPOR INFORMATION		
Vapor Mass Flow	LB/H	0
Vapor Mass Density	PCF	0
Vapor Specific Heat Capacity	BTU/LB/DEG F	
Vapor Conductivity	BTU/H/FT/DEG F	

Observe that 756.5 gpm is 10 percent higher than 687.74 gpm, which is equivalent to the liquid mass flow rate, 160,645 lb/hr. When the effluent stream, *ICP-BE_2*, is clicked on, the stream report does not display the stream properties because the stream has been *referenced* to the *ICP-BE* stream.

This procedure is repeated to add other equipment items, which may be added to the *New Item* area or to other new areas.

To estimate the installed cost of the *Reboiler pump*, either right click on *Reboiler pump* in the *Project View* or on its icon in the *Process Flow Diagram.* Then, select *Evaluate Item*. A brief report that contains the installed cost, $49,400, can be accessed by highlighting *Reboiler pump* in the *Project View* and pressing the *List* tab to obtain the *Workbook.* A complete report is obtained by re-evaluating the capital estimates for the process. This is accomplished by pressing the *Evaluate Project* button and requesting that all equipment items be re-evaluated. The detailed report appears in the *Capital Estimate Report* in the *List of Equipment and Bulk Material by Area* section. It can be accessed by selecting *Equipment List* under *Miscellaneous Flowsheet* in the left-hand window: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Title page
Contract structure
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PROJECT SUMMARY
PROJECT DATA SHE
PROJECT SCHEDULI
CONTRACT NO. 1 F
SUMMARIES BY REF
1. Main Area
Equipment List
Report group cost
2. Miscellaneous Flow
Equipment List
Report group cost
3. NewItem
Equipment List
Report group cost
Design data sheets
Detailed bulks
Bulk summary, groups
Bulk summary, total
Major account summa
Units of measure data
Input stats
Barcharts
0201 Miscellaneous Flowsheet - Miscellaneous Flowsheet
C O M P O N E N T L I S T
ORIGIN : ITEM TYPE : I T E M : D E S C R I P T I O N : D E S I G N D A T A
CP - 8 CENTRIF Reboiler Pump
CODE OF ACCOUNT: 161
Casing material CS
Liquid flow rate 756.52 GPM
Fluid head 20.00 FEET
Design temperature 298.99 DEG F
Speed 3600.00 RPM
Driver power 3.000 HP
Fluid viscosity 0.00000200 CPOISE
Design gauge pressure 262.00 PSIG
Driver type MOTOR
Seal type SNGL
Total weight 630 LBS
ITEM :--- M A T E R I A L ---:********* M A N P O W E R *********:--- L/M ---:
: FRACTION : FRACTION : RATIO :
: USD OF PE : USD OF PE MANHOURS : USD/USD :
EQUIPMENT&SETTING: 8100. 1.0000 : 542. 0.0669 23 : 0.067 :
PIPING : 16439. 2.0295 : 6255. 0.7722 256 : 0.380 :
CIVIL : 190. 0.0235 : 574. 0.0709 30 : 3.019 :
STRUCTURAL STEEL : 0. 0.0000 : 0. 0.0000 0 : 0.000 :
INSTRUMENTATION : 7067. 0.8725 : 2081. 0.2569 80 : 0.294 :
ELECTRICAL : 674. 0.0832 : 1013. 0.1250 42 : 1.503 :
INSULATION : 3205. 0.3957 : 2404. 0.2967 113 : 0.750 :
PAINT : 247. 0.0304 : 572. 0.0706 31 : 2.320 :
SUBTOTAL : 35922. 4.4349 : 13440. 1.6592 575 : 0.374 :
TOTAL MATERIAL AND MANPOWER COST =USD 49400. INST'L COST/PE RATIO = 6.099
For Help, press F1
INS
NUM
Ln 3000 of 10029
4:50 PM

Note that no equipment items remain in the *New Item* section of the report.

Having added the *Reboiler pump*, the total permanent investment can be re-estimated as discussed in the prior section. This discussion is not repeated here.

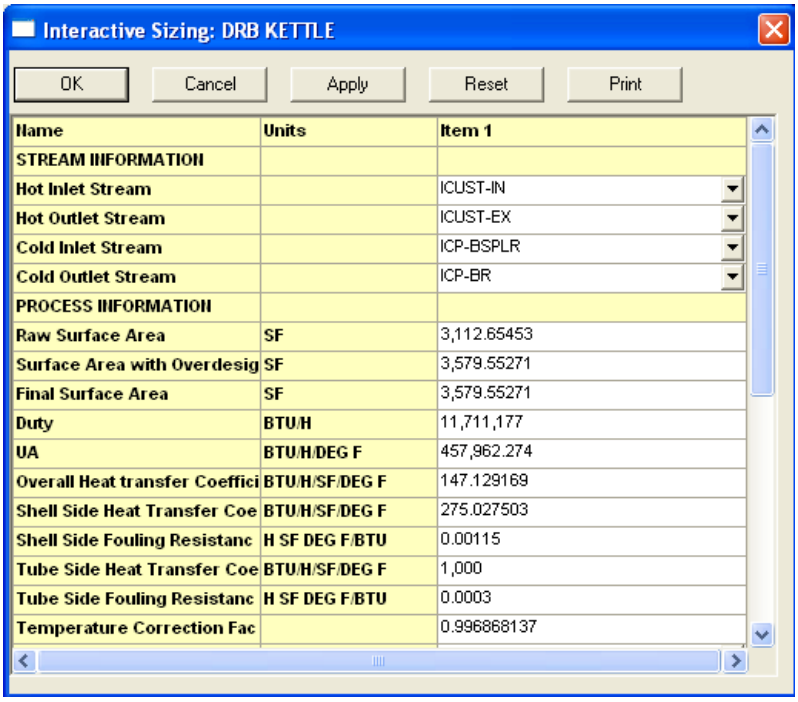
Finally, all of the Aspen IPE results can be reproduced using the DEC3RP folder (in the ASPEN folder on the Wiley web site) from within Aspen IPE.

Applying Alternative Utilities

When desired, the default utility applied by Aspen IPE can be altered interactively for a particular equipment item, such as a condenser or reboiler, after it has been mapped. For example, when the resulting surface area of a reboiler is too large due to a small log-mean-temperature-difference, the steam utility can be replaced with steam at a higher pressure to reduce the area, being careful to stay in the nucleate boiling region.

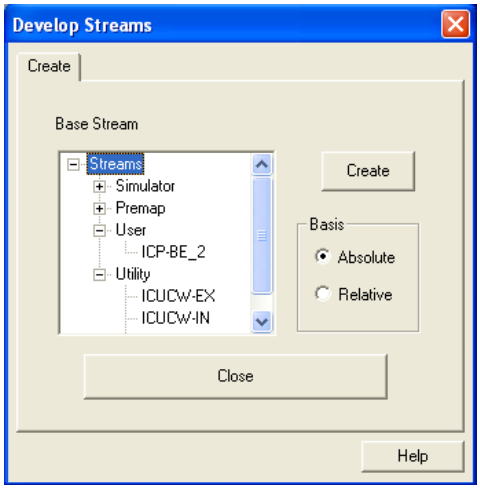
This is illustrated for the reboiler of the depropanizer as an example. For this reboiler, Aspen IPE uses steam at 50 psi as the default utility. To change to higher-pressure steam, say at 100 psi, the following steps are taken.

In the *Process View* or *Process Flow Diagram*, right click on the reboiler and select *Size Item* from the menu that appears. This produces the *Interactive Sizing* dialog box, as shown below:



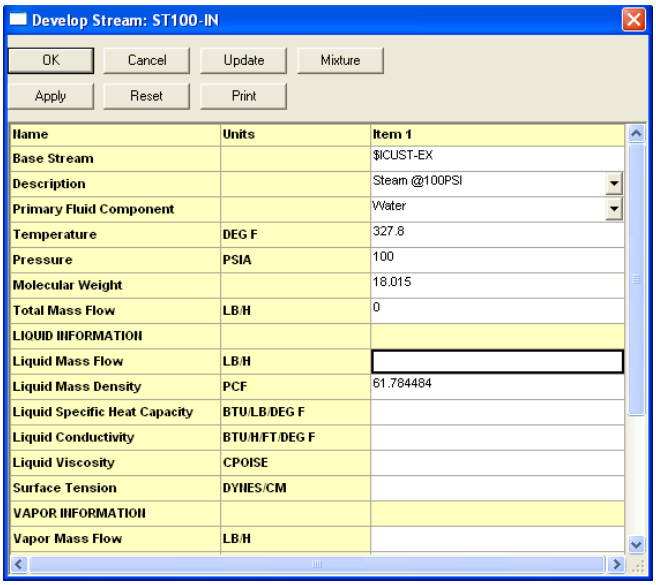
Name	Units	Item 1
STREAM INFORMATION		
Hot Inlet Stream		ICUST-IN
Hot Outlet Stream		ICUST-EX
Cold Inlet Stream		ICP-BSPLR
Cold Outlet Stream		ICP-BR
PROCESS INFORMATION		
Raw Surface Area	SF	3,112.65453
Surface Area with Overdesig	SF	3,579.55271
Final Surface Area	SF	3,579.55271
Duty	BTU/H	11,711,177
UA	BTU/H/DEG F	457,962.274
Overall Heat transfer Coeffici	BTU/H/SF/DEG F	147.129169
Shell Side Heat Transfer Coe	BTU/H/SF/DEG F	275.027503
Shell Side Fouling Resistanc	H SF DEG F/BTU	0.00115
Tube Side Heat Transfer Coe	BTU/H/SF/DEG F	1,000
Tube Side Fouling Resistanc	H SF DEG F/BTU	0.0003
Temperature Correction Fac		0.996868137

In the *Item 1* column that contains the values, the items for *Hot Inlet Stream* and *Hot Outlet Stream* are *ICUST-IN* and *ICUST-EX*, respectively, which correspond to the default utility, in this case, steam at 50 psi. To change to steam at 100 psi, new user streams for the inlet and outlet must replace the default utility streams created by Icarus. To accomplish this, go to the *Process Flow Diagram* (accessible from the *View*) menu, right click on the *ICUST-IN* stream (which is green, leading into the D1-reboiler), and choose *Delete*. Then, click on the *Add Stream* button in the toolbar ( ). This gives the *Develop Streams* dialog box:

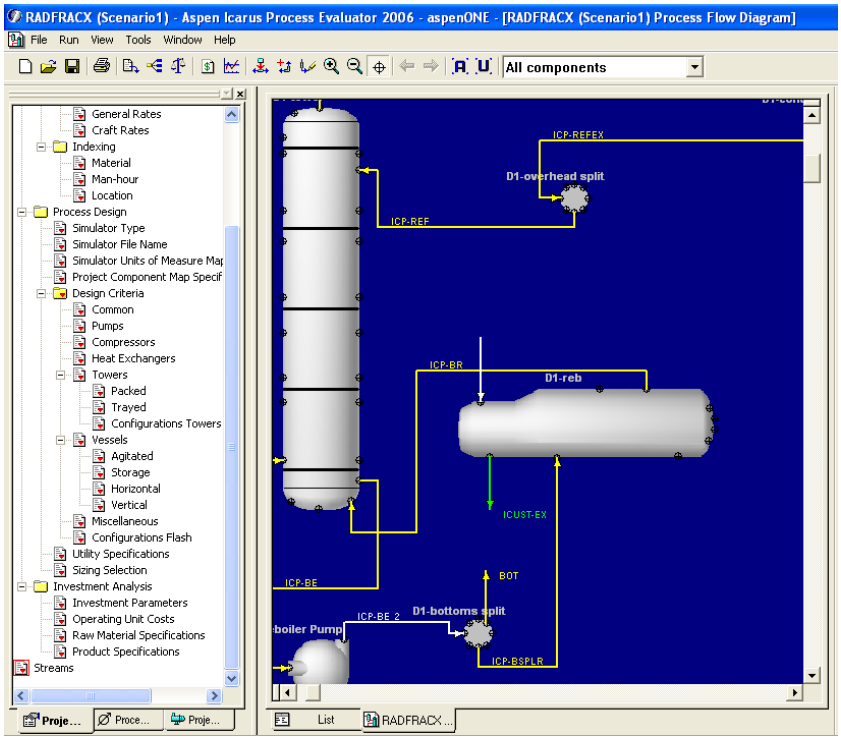


First, select a basis stream, by highlighting *ICUST-EX* in the Utility subsection. Its properties (such as molecular weight, etc) are copied into the new stream. Leave the radio button set to *Absolute*. Then, click on the *Create* button and type

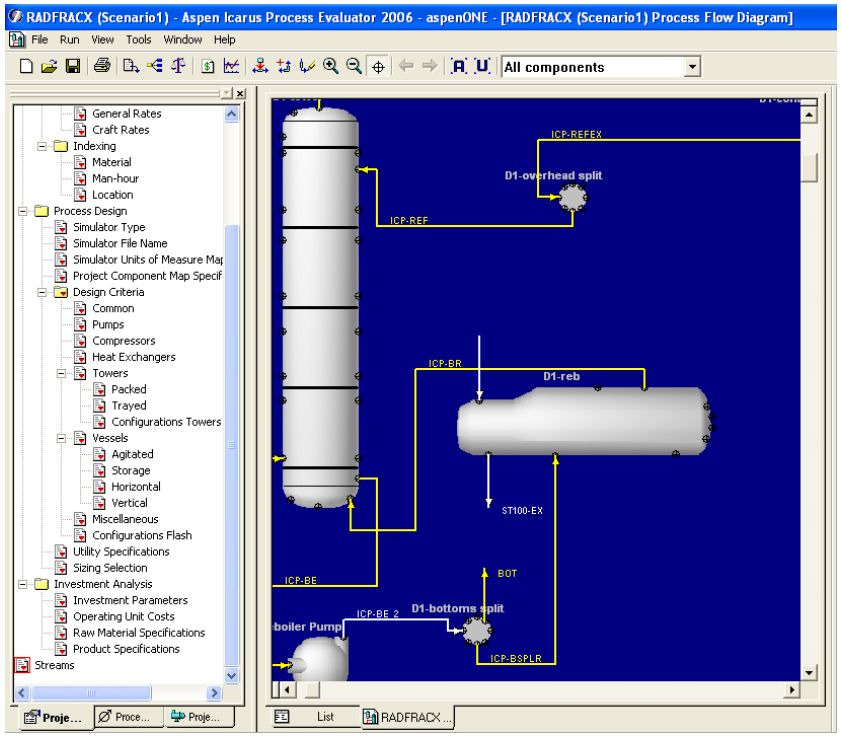
a name for the new stream, such as *ST100-IN*. In the next dialogue box, enter "Steam @100PSI" as the description, and change the temperature and pressure to that of saturated steam at 100 psia (327.8ºF). Delete the entry for the total mass flow, as it is recalculated by Aspen IPE, as shown below.



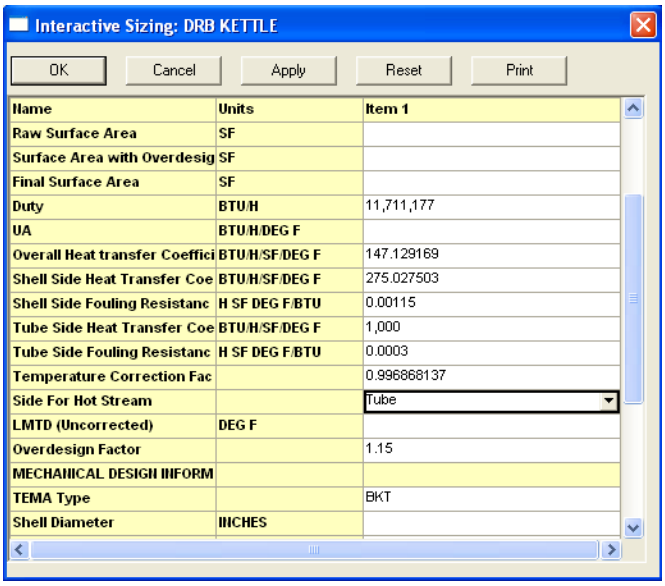
Click the *OK* button to accept these changes. Now, the new stream must be attached to the reboiler. With the *Ports Visible* button ( )depressed, click on *Draw Disconnected Stream* ( ). Select the new stream from the list, and add it to the flowsheet by left clicking on the reboiler. Then left click again on the steam entry port. Not that the port is highlighted in green as the cursor hovers over it. The new stream now appears in white as shown below.



Now, repeat this procedure for the exit stream, replacing it with a new user stream named ST100-EX, using ST100-IN as the basis stream. The result is shown below:

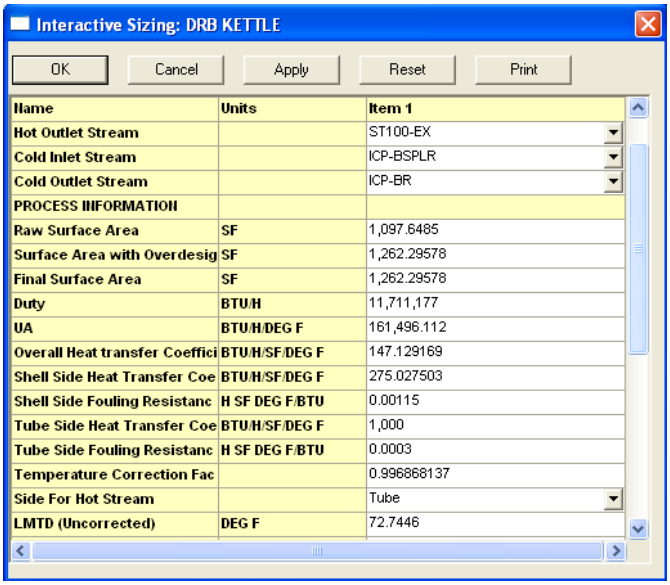


Next, the reboiler is sized using the new utility specifications. Right click on the reboiler and choose *Size Item*. Delete the values for the *Raw Surface Area*, *Surface Area with Overdesign*, *Final Surface Area*, *UA*, and *LMTD (Uncorrected)*, as shown below. When *OK* is pressed, these variables are recalculated using the properties of the new steam streams.



Name	Units	Item 1
Raw Surface Area	SF	
Surface Area with Overdesig	SF	
Final Surface Area	SF	
Duty	BTU/H	11,711,177
UA	BTU/H/DEG F	
Overall Heat transfer Coeffici	BTU/H/SF/DEG F	147.129169
Shell Side Heat Transfer Coe	BTU/H/SF/DEG F	275.027503
Shell Side Fouling Resistanc	H SF DEG F/BTU	0.00115
Tube Side Heat Transfer Coe	BTU/H/SF/DEG F	1,000
Tube Side Fouling Resistanc	H SF DEG F/BTU	0.0003
Temperature Correction Fac		0.996868137
Side For Hot Stream		Tube
LMTD (Uncorrected)	DEG F	
Overdesign Factor		1.15
MECHANICAL DESIGN INFORM		
TEMA Type		BKT
Shell Diameter	INCHES	

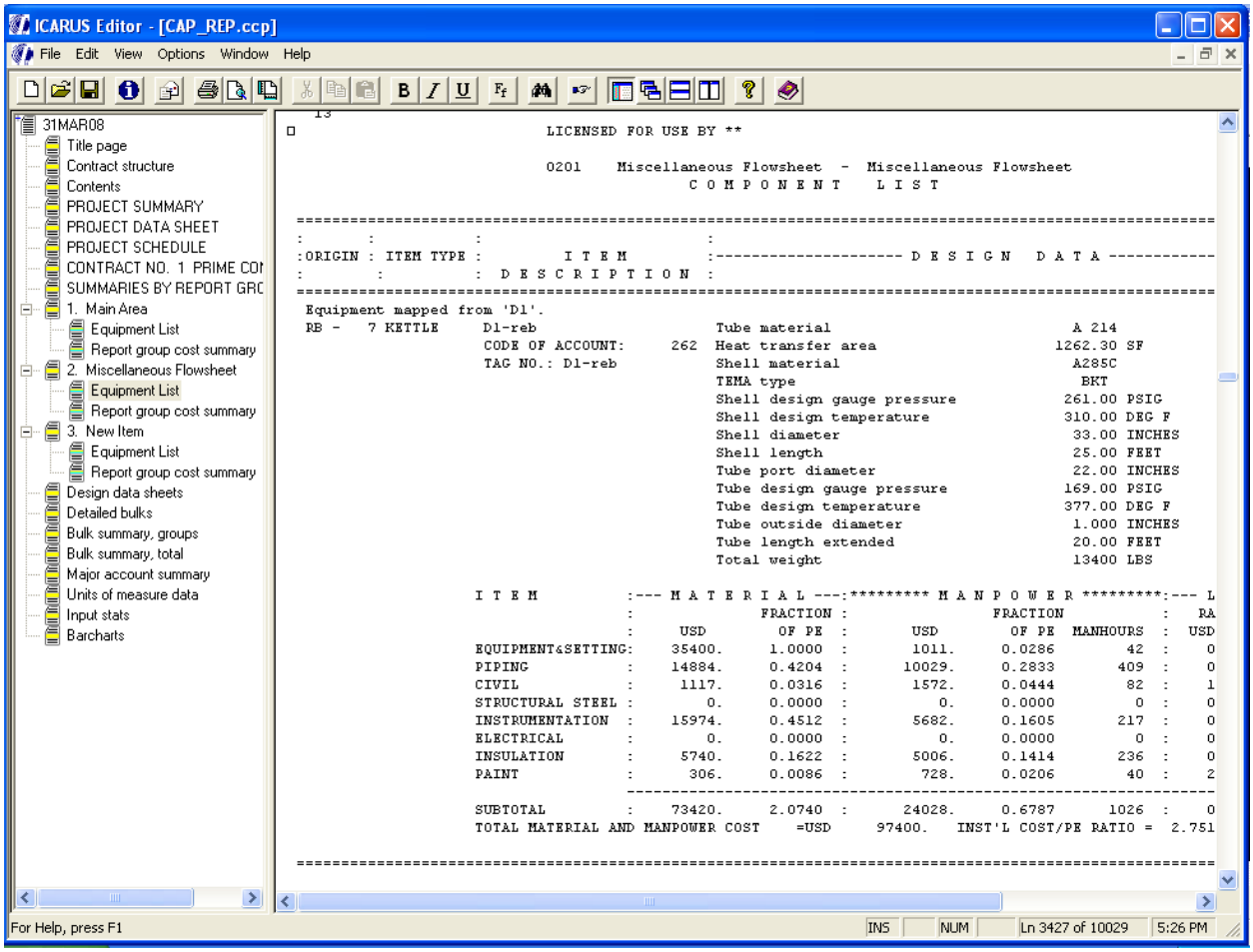
After the reboiler is re-sized, right click on the reboiler and again select *Size Item* to view the calculated results:



Name	Units	Item 1
Hot Outlet Stream		ST100-EX
Cold Inlet Stream		ICP-BSPLR
Cold Outlet Stream		ICP-BR
PROCESS INFORMATION		
Raw Surface Area	SF	1,097.6485
Surface Area with Overdesig	SF	1,262.29578
Final Surface Area	SF	1,262.29578
Duty	BTU/H	11,711,177
UA	BTU/H/DEG F	161,496.112
Overall Heat transfer Coeffici	BTU/H/SF/DEG F	147.129169
Shell Side Heat Transfer Coe	BTU/H/SF/DEG F	275.027503
Shell Side Fouling Resistanc	H SF DEG F/BTU	0.00115
Tube Side Heat Transfer Coe	BTU/H/SF/DEG F	1,000
Tube Side Fouling Resistanc	H SF DEG F/BTU	0.0003
Temperature Correction Fac		0.996868137
Side For Hot Stream		Tube
LMTD (Uncorrected)	DEG F	72.7446

Using steam at 100 psi, the *final surface area* is 1,262 ft^2, reduced from 3,580 ft^2, while the log-mean-temperature-difference is 72.7°F, increased from 25.7°F.

Finally, the capital cost of the entire process is re-evaluated since the cost of the smaller reboiler is lower. This is accomplished by pressing the *Evaluate Project* button on the toolbar and selecting *Evaluate All Items*. The results appear in the *Capital Estimate Report* in the *List of Equipment and Bulk Material by Area* section. They are accessed by selecting *Equipment List* under *Miscellaneous Flowsheet* in the left-hand window: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Contract structure
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PROJECT SUMMARY
PROJECT DATA SHEET
PROJECT SCHEDULE
CONTRACT NO. 1 PRIME CON
SUMMARIES BY REPORT GRO
1. Main Area
Equipment List
Report group cost summary
2. Miscellaneous Flowsheet
Equipment List
Report group cost summary
3. New Item
Equipment List
Report group cost summary
Design data sheets
Detailed bulks
Bulk summary, groups
Bulk summary, total
Major account summary
Units of measure data
Input stats
Barcharts
LICENSED FOR USE BY **
0201 Miscellaneous Flowsheet - Miscellaneous Flowsheet
C O M P O N E N T L I S T
Equipment mapped from 'D1'.
RB - 7 KETTLE D1-reb
CODE OF ACCOUNT: 262
TAG NO.: D1-reb
Tube material A 214
Heat transfer area 1262.30 SF
Shell material A285C
TEMA type BKT
Shell design gauge pressure 261.00 PSIG
Shell design temperature 310.00 DEG F
Shell diameter 33.00 INCHES
Shell length 25.00 FEET
Tube port diameter 22.00 INCHES
Tube design gauge pressure 169.00 PSIG
Tube design temperature 377.00 DEG F
Tube outside diameter 1.000 INCHES
Tube length extended 20.00 FEET
Total weight 13400 LBS
ITEM --- MATERIAL --- MANPOWER
USD FRACTION OF PE USD FRACTION OF PE MANHOURS
EQUIPMENT&SETTING: 35400. 1.0000 1011. 0.0286 42 0
PIPING 14884. 0.4204 10029. 0.2833 409 0
CIVIL 1117. 0.0316 1572. 0.0444 82 1
STRUCTURAL STEEL 0. 0.0000 0. 0.0000 0 0
INSTRUMENTATION 15974. 0.4512 5682. 0.1605 217 0
ELECTRICAL 0. 0.0000 0. 0.0000 0 0
INSULATION 5740. 0.1622 5006. 0.1414 236 0
PAINT 306. 0.0086 728. 0.0206 40 2
SUBTOTAL 73420. 2.0740 24028. 0.6787 1026 0
TOTAL MATERIAL AND MANPOWER COST =USD 97400. INST'L COST/PE RATIO = 2.751
For Help, press F1
INS NUM Ln 3427 of 10029 5:26 PM

These steps are repeated when it is desired to change the default utilities for other equipment items in the process.

Furthermore, for most equipment items, other specifications can be adjusted using interactive sizing. This can be accomplished for condensers, reboilers, flash drums, reflux accumulators, storage vessels, pumps, and compressors. Note, however, that interactive sizing is not possible for reactor vessels. For a complete listing of equipment items that can be sized interactively, refer to the chapter on *Sizing Project Components* in the *Aspen IPE User's Guide* (*Aspen Icarus Process Evaluator User's Manual* → *Sizing Project Components*).

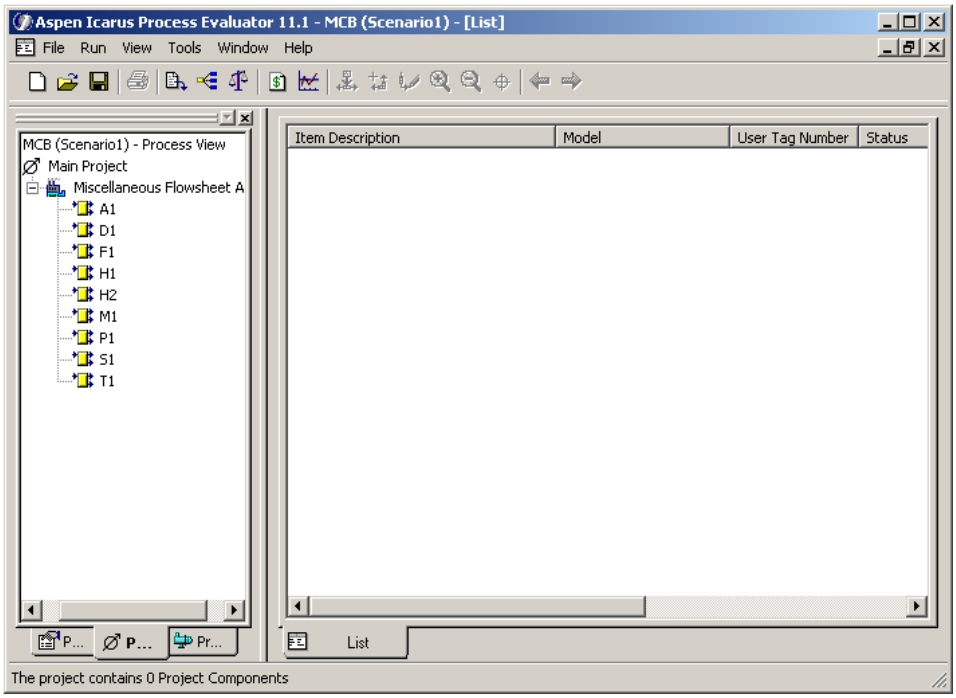
MONOCHLOROBENZENE SEPARATION PROCESS

In this section, equipment sizes and costs are estimated for the monochlorobenzene (MCB) separation process, which is discussed in Section 5.4 of the textbook and in the multimedia module on the Wiley web site for this book (*ASPEN* → *Principles of Flowsheet Simulation* → *Interpretation of Input and Output* → *Sample Problem*). Beginning with the file, MCB.bkp, which is available in the ASPEN folder on the Wiley web site, additional mixture properties are added and the DISTL subroutine, used to model the D1 distillation column, is replaced with the RADFRAC subroutine. The reflux ratio computed using the RADFRAC subroutine is 3.35, as compared with 4.29 computed using the approximate DISTL subroutine. Also, the stream flow rates differ slightly (< 1%). Both of the files, MCB-IPE.bkp and MCB-IPE.rep, are in the ASPEN folder on the Wiley web site.

Initial Setup

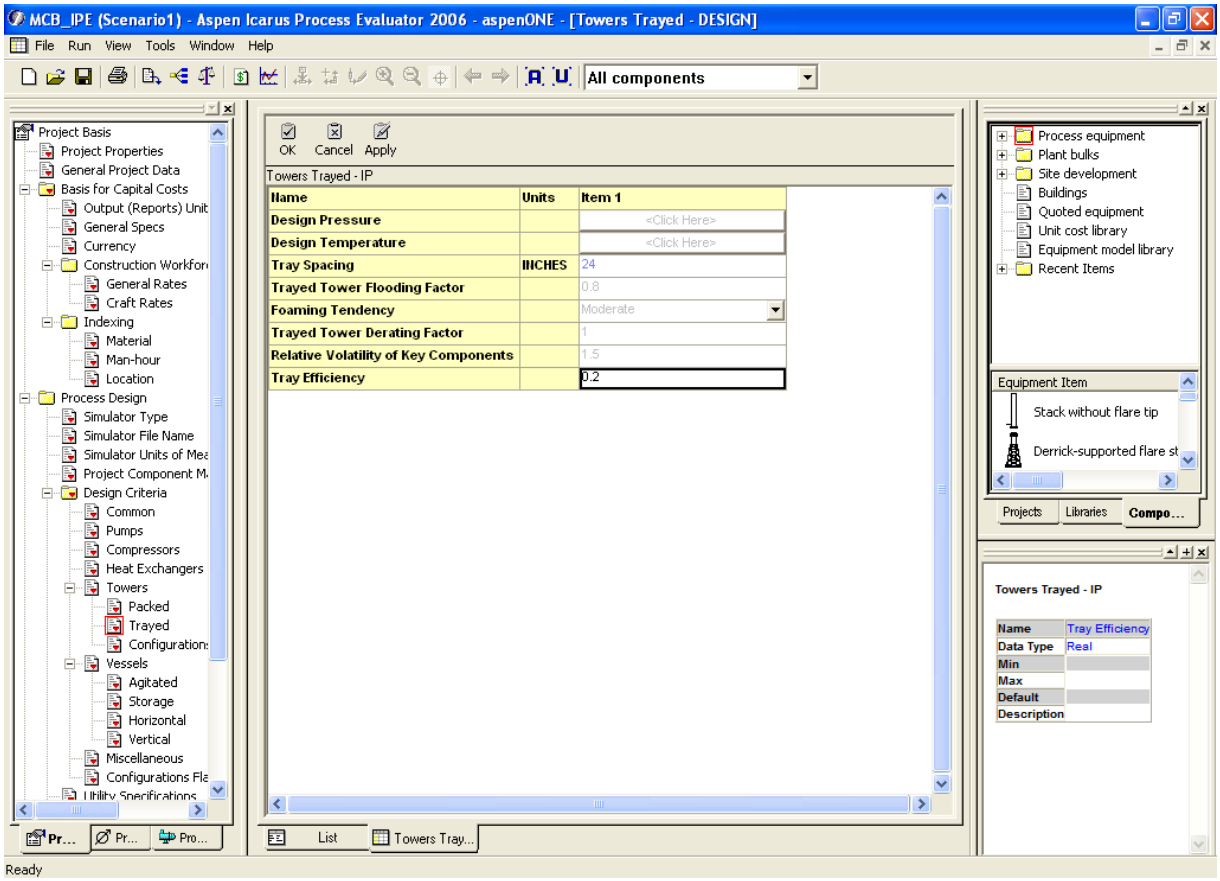
After sending the file, MCB-IPE.rep to *Aspen Icarus*, the user is ready to use Aspen IPE. Aspen IPE is opened automatically and the *Create New Project* dialog box appears. After the Project Name MCB is entered, the *Inch-Pound* (IP) unit set is selected in the *Project Properties* dialog box.

After *OK* is pressed, Aspen IPE loads the information associated with each process model in ASPEN PLUS. When completed, the IPE *Main* window appears:



The MCB separation process has two types of columns, an absorber and a distillation column, each having a distinct tray efficiency. Absorber efficiencies are normally low, at roughly 20%, while efficiencies for distillation columns are considerably higher, in this case at about 60%. This difference must be taken into account when proceeding with Aspen IPE.

Because Aspen IPE allows only one specification for the tray efficiency, it is necessary to map and size each of the columns separately, with the appropriate efficiency specified in the *Design Criteria* prior to each mapping. Note that to locate the tray efficiency, open the *Design Criteria* folder, then the *Towers* folder, and finally the *Trayed* entry, to give:

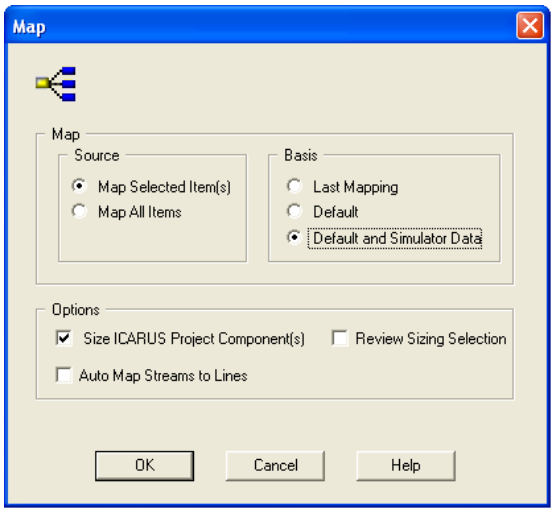


To size the absorber column (A1-block), a tray efficiency of 0.2 (or 20%) is entered. No other changes to the default values are necessary.

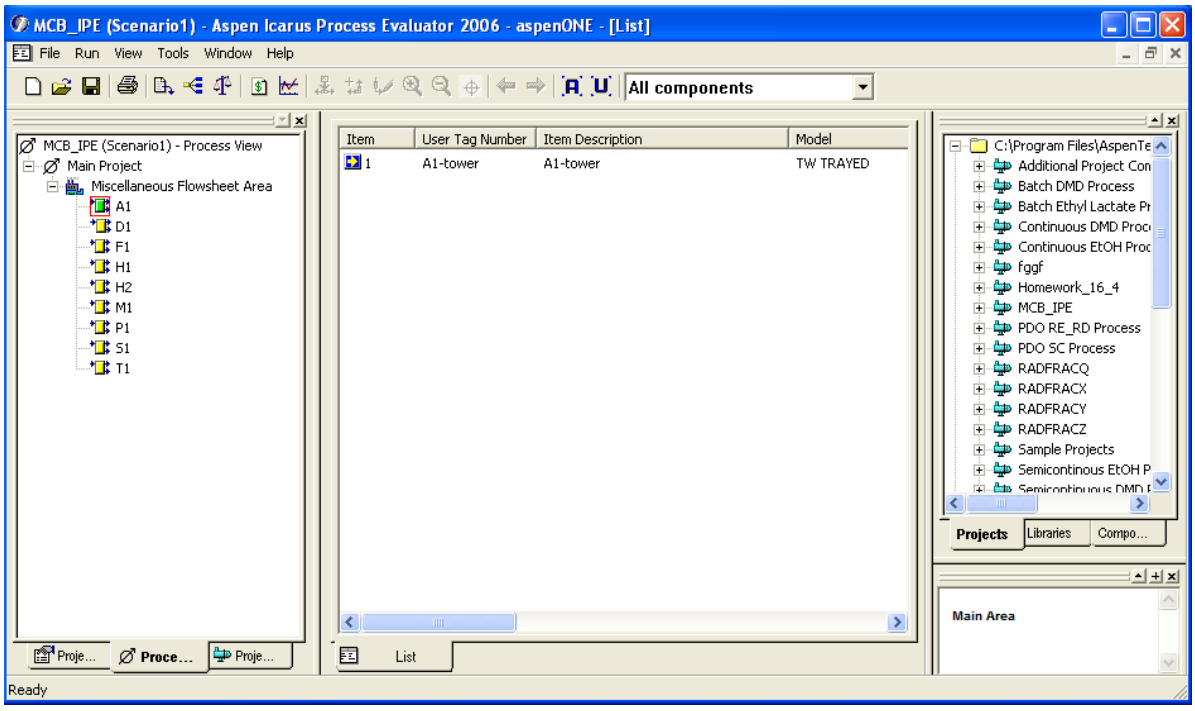
Changes to the *Utility Specifications*, such as the cooling water temperatures, are made at this point.

Mapping Process Simulation Units to Aspen IPE

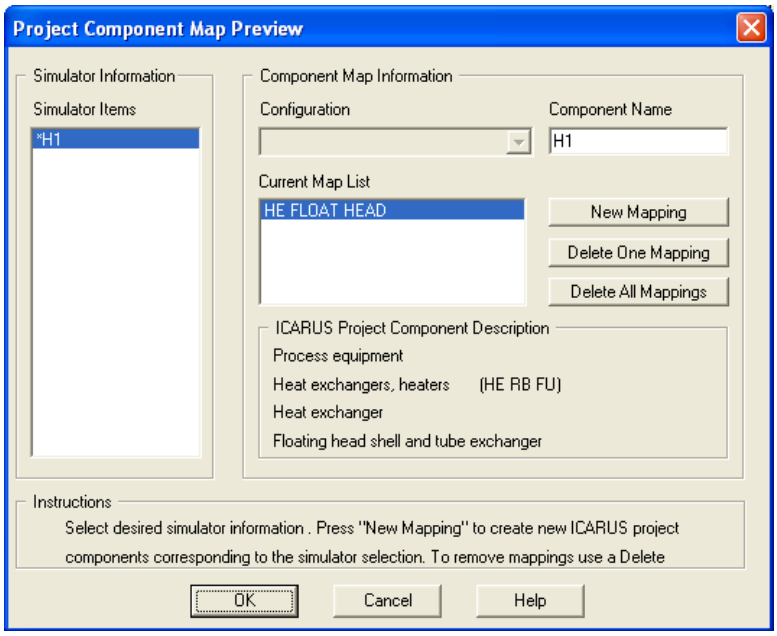
To map a single process unit, right-click on the selected item on the Aspen IPE *Main* window, and choose *Map.* In the *Map* dialog box, select *Map Selected Item(s)*, and use *Default and Simulator Data* as the basis:



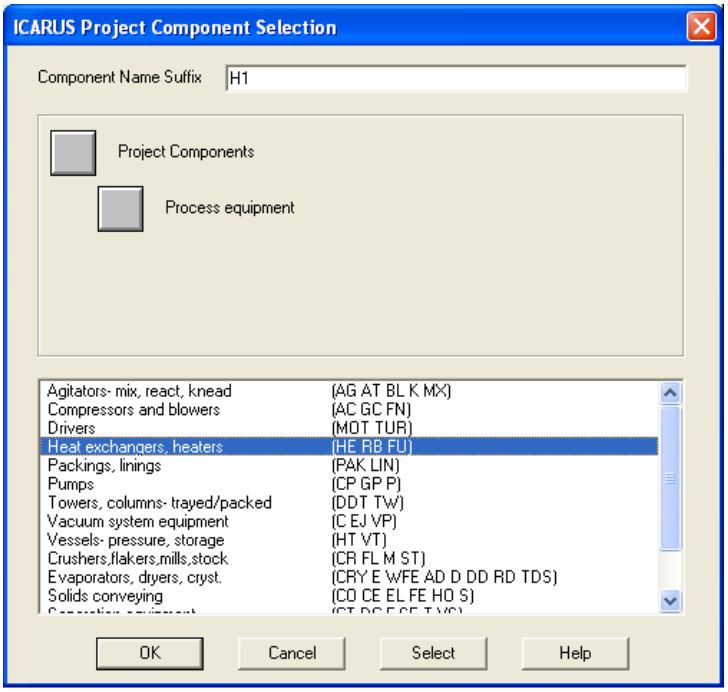
Press *OK* to produce the *Project Component Map Preview* dialog box (not shown here). Since the *Current Map List* does not need to be altered, select *OK* to map the A1 unit. When the mapping and equipment sizing has been completed, the A1 unit has been added to the list *of Project Components*, as shown below:



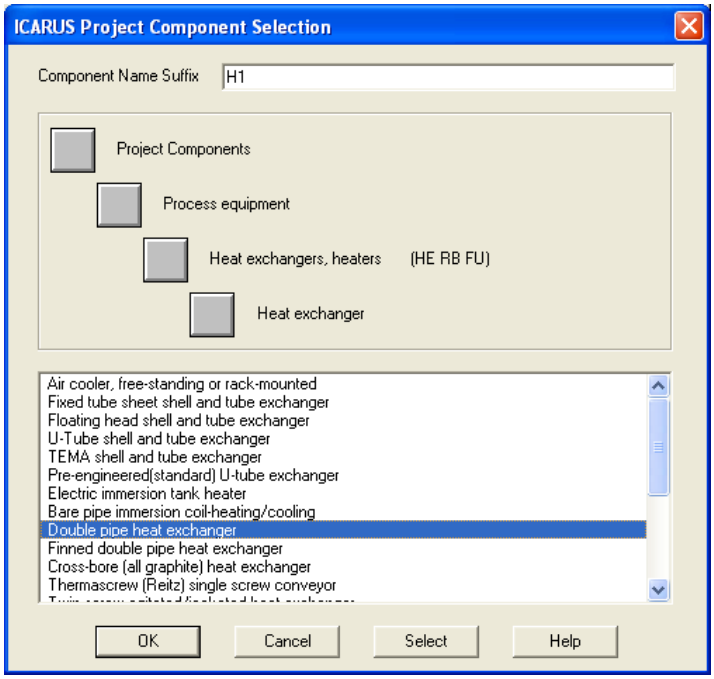
Before mapping the distillation unit, D1, the tray efficiency is changed to 0.6 in the *Design Criteria*. Subsequently, each of the remaining equipment items is mapped and sized, one at a time, as described above. Note that the unit H1 is too small to be mapped as a floating-head heat exchanger. Consequently, it is necessary to change the default equipment type to a *Double-pipe heat exchanger*, which is more appropriate for this application. To change the mapping, select *HE FLOAT-HEAD* in the *Current Map List* and press the *Delete One Mapping* button:



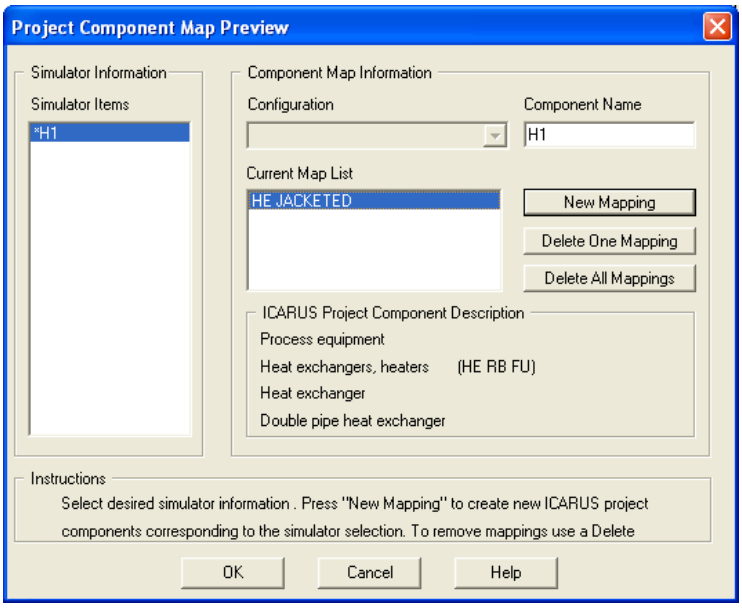
Then, select *New Mapping*, *Heat exchangers*, and then *heaters* to give:


ICARUS Project Component Selection
Component Name Suffix
H1
Project Components
Process equipment
Agitators- mix, react, knead (AG AT BL K MX)
Compressors and blowers (AC GC FN)
Drivers (MOT TUR)
Heat exchangers, heaters (HE RB FU)
Packings, linings (PAK LIN)
Pumps (CP GP P)
Towers, columns- trayed/packed (DDT TW)
Vacuum system equipment (C EJ VP)
Vessels- pressure, storage (HT VT)
Crushers,flakers,mills,stock (CR FL M ST)
Evaporators, dryers, cryst. (CRY E WFE AD D DD RD TDS)
Solids conveying (CO CE EL FE HO S)
OK
Cancel
Select
Help

From the next dialog box, select *Heat exchanger* and finally choose the *Double-pipe heat exchanger*:



After these steps are completed, the *Current Map List* is modified in the *Project Component Map Preview* dialog box:

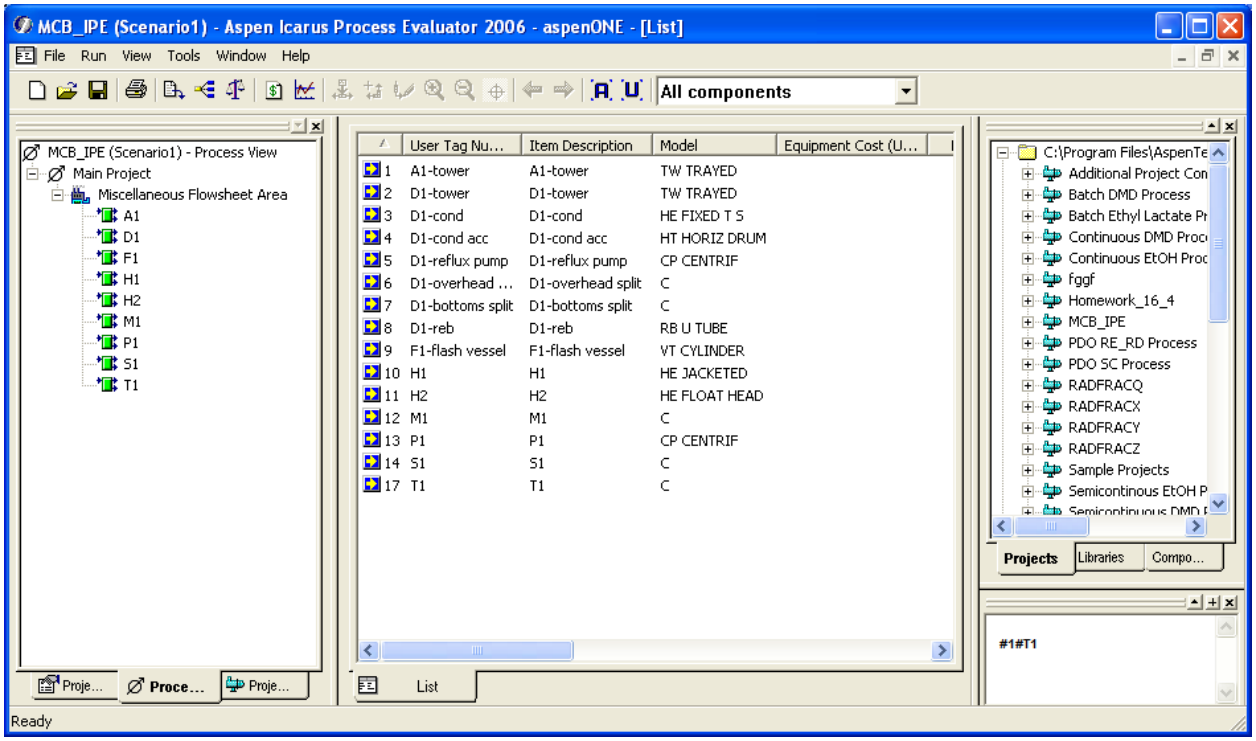


Note that when the sizing calculations are being carried out for the flash vessel, F1, two *Message* dialog boxes appear. The first indicates that the diameter is calculated to be 2.007 ft, but that the user-specified minimum value of 3 ft is used instead. The second indicates that the L/D ratio is 1.67, rather than 3.0 from the *Design Criteria.* Also, for the heat exchanger, H1, a 1-degree difference between the inlet and outlet

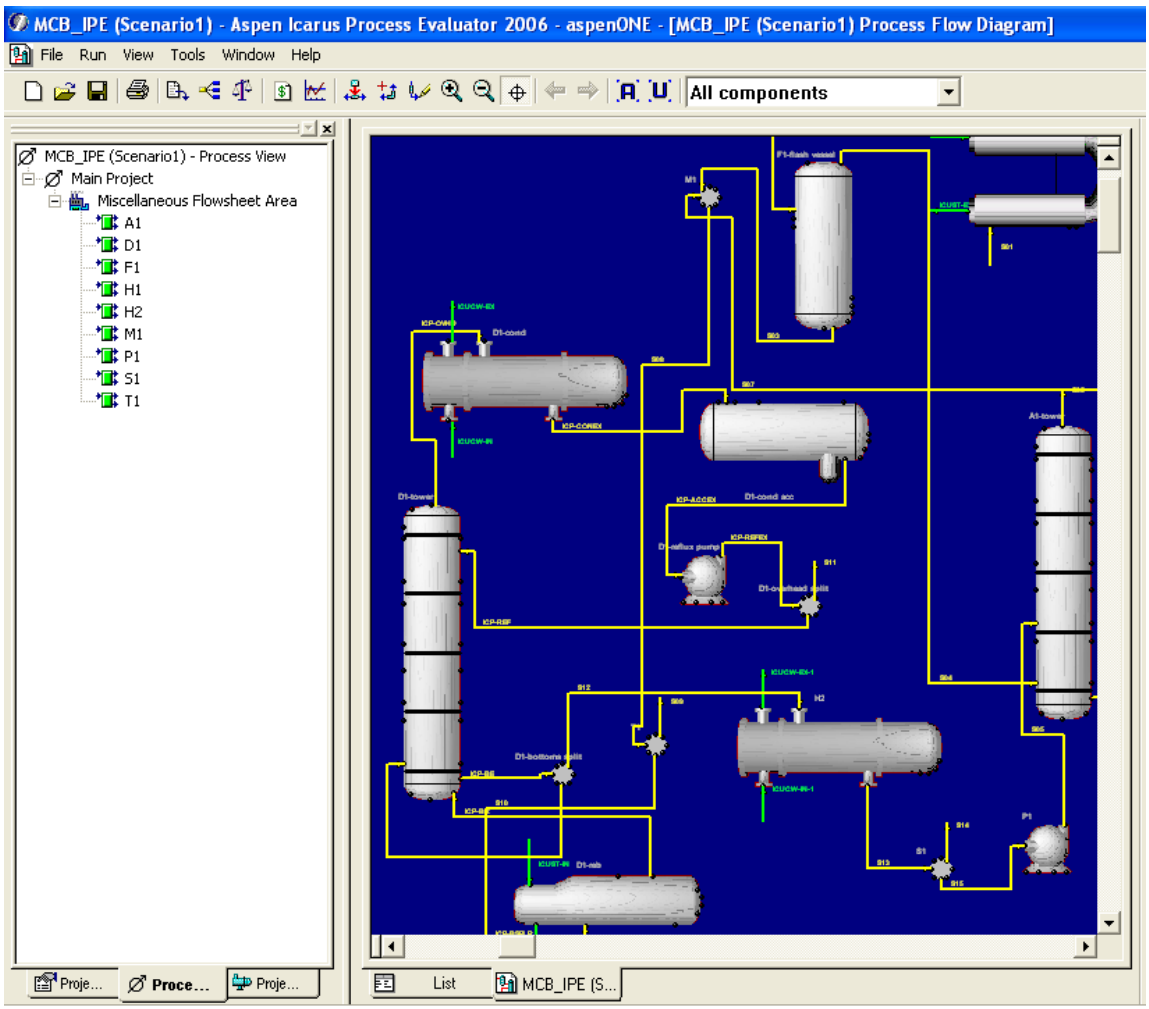
temperatures of the hot stream is assumed. The unit M1 is a mixing junction between two pipes and the unit S1 is a simple pipeline splitter. Size and cost estimates are not needed for these units. The unit T1 represents a treater, which is not being considered at this point in the design of the MCB separation process.

Aspen IPE maps the mixer M1 and splitter S1 as *Quoted Items* with zero cost. The default mapping for the treater T1 is a *VT CYLINDER*, with size and cost estimates computed. This default mapping is replaced with a *Quoted Item* having zero cost. To accomplish this, delete the mapping for T1. In the *Project View*, right click on T1, then on *Map*. On the *Map* dialog box, click on *OK* to produce the *Project Component Map Preview* dialog box. Delete the *VT CYLINDER* mapping and click on *New Mapping*, to produce the *ICARUS Project Component Selection* dialog box. Click on *Project Components*, select *Quoted equipment*, and click *OK*. This places the unit T1 into the *List View* with a *C*, to indicate that it is a *Quoted Item* having zero cost.

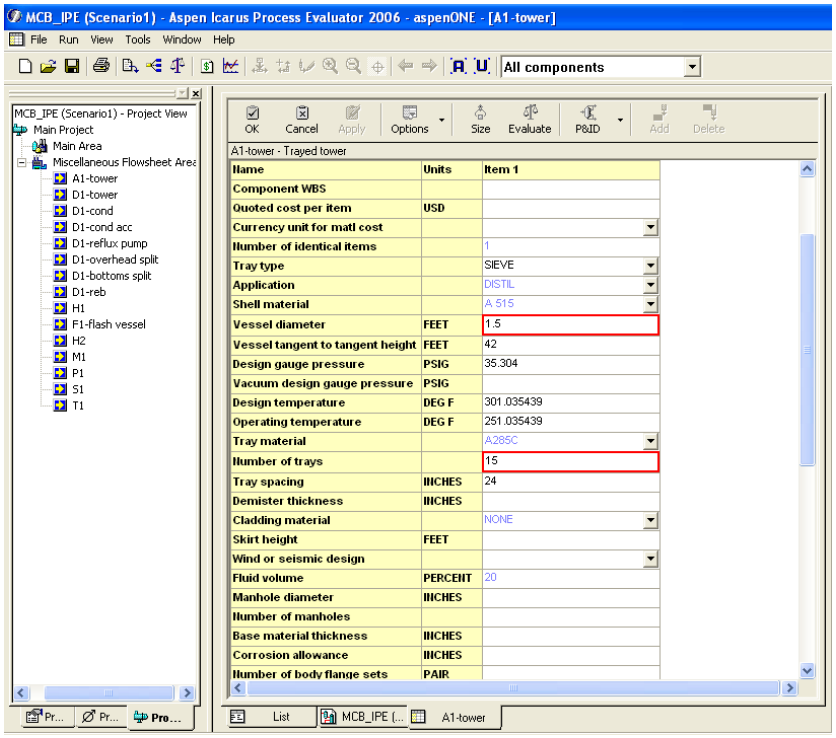
After all of the equipment items have been mapped and sized successfully, the IPE *Main* window is displayed:



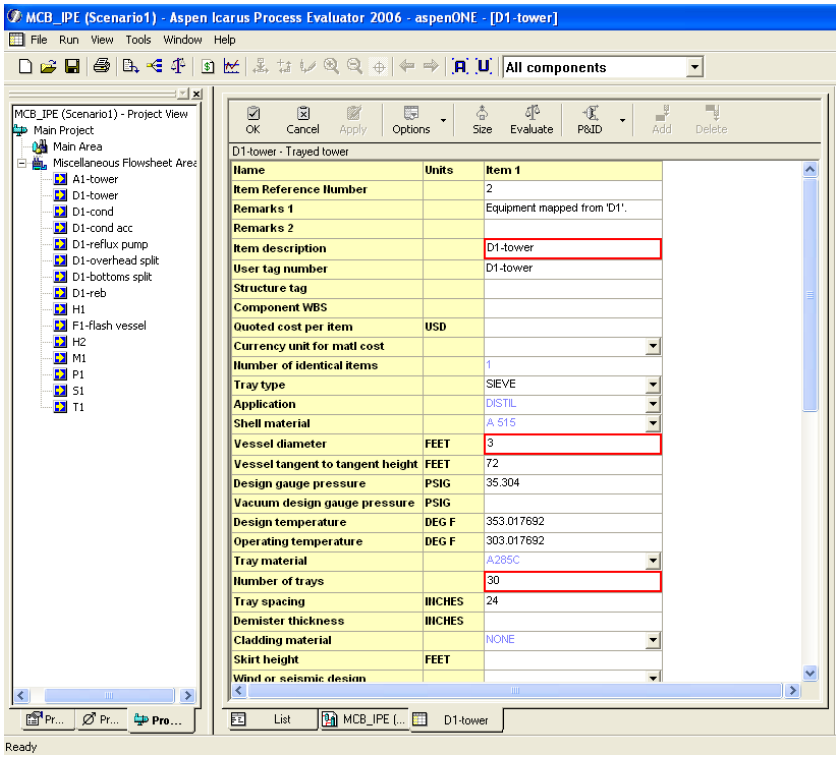
Note that the five *C* entries represent *Quoted Items* having zero cost. The associated *Process Flow Diagram*, after some reorganizing, is:



When the mapping and sizing are completed it is prudent to check the equipment sizes computed by Aspen IPE, especially for major equipment items such as towers, large heat exchangers, compressors, and chemical reactors. For the MCB separation process, the two towers are of particular interest. To view the Aspen IPE result for an equipment item, double click on the item of interest in the IPE *Main* window. For the absorber, this produces the following results:


MCB_IPE (Scenario1) - Aspen Icarus Process Evaluator 2006 - aspenONE - [A1-tower]
File Run View Tools Window Help
All components
MCB_IPE (Scenario1) - Project View
Main Project
Main Area
Miscellaneous Flowsheet Area
A1-tower
D1-tower
D1-cond
D1-cond acc
D1-reflux pump
D1-overhead split
D1-bottoms split
D1-reb
H1
F1-flash vessel
H2
M1
P1
S1
T1
OK Cancel Apply Options Size Evaluate P&ID Add Delete
A1-tower - Trayed tower
Name | Units | Item 1
Component WBS
Quoted cost per item | USD
Currency unit for matl cost
Number of identical items | 1
Tray type | SIEVE
Application | DISTIL
Shell material | A 515
Vessel diameter | FEET | 1.5
Vessel tangent to tangent height | FEET | 42
Design gauge pressure | PSIG | 35.304
Vacuum design gauge pressure | PSIG
Design temperature | DEG F | 301.035439
Operating temperature | DEG F | 251.035439
Tray material | A285C
Number of trays | 15
Tray spacing | INCHES | 24
Demister thickness | INCHES
Cladding material | NONE
Skirt height | FEET
Wind or seismic design
Fluid volume | PERCENT | 20
Manhole diameter | INCHES
Number of manholes
Base material thickness | INCHES
Corrosion allowance | INCHES
Number of body flange sets | PAIR
List MCB_IPE (... A1-tower

Note that the column is designed to have a 1.5 ft diameter, a 42 ft (tangent-to-tangent) height, and 15 trays, in accordance with the specifications in Figure 5.23 of the textbook (Seider et al., 2009). Because of the small diameter, a packed column would be preferred, but is not considered here.



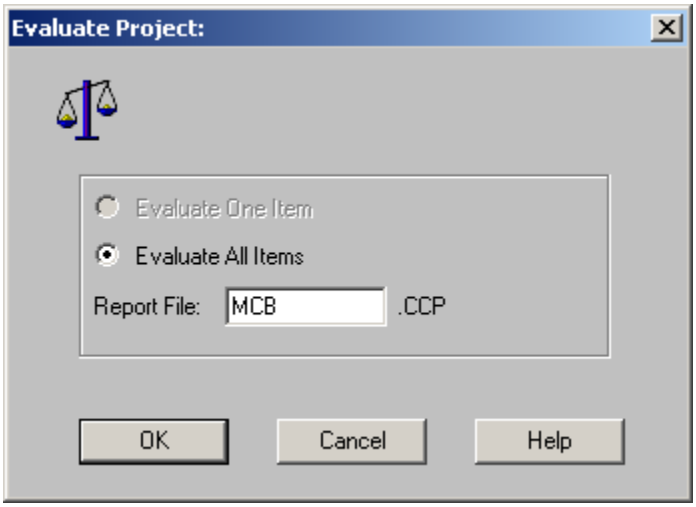
Similarly, the distillation column is designed to have a 3 ft diameter, a 72 ft (tangent-to tangent) height, and 30 trays, also in accordance with Figure 5.23 in the textbook (Seider et al., 2009).

Standard Basis

As for the depropanizer discussed earlier, the MCB separation process can be viewed as representing an addition to an existing plant. Consequently, the standard basis profile is selected to be *LOCAL CONTRACTOR* and the *Project Type* is selected as *Plant addition – suppressed infrastructure*.

Equipment Costing

Aspen IPE estimates purchase and installed costs for the equipment units individually or for the entire project using a single command. For the MCB separation process, it is convenient to have Aspen IPE estimate the costs for the entire project at once. After pressing the *Evaluate Project* button on the IPE *Main* window, the *Evaluate Project* dialog box appears:



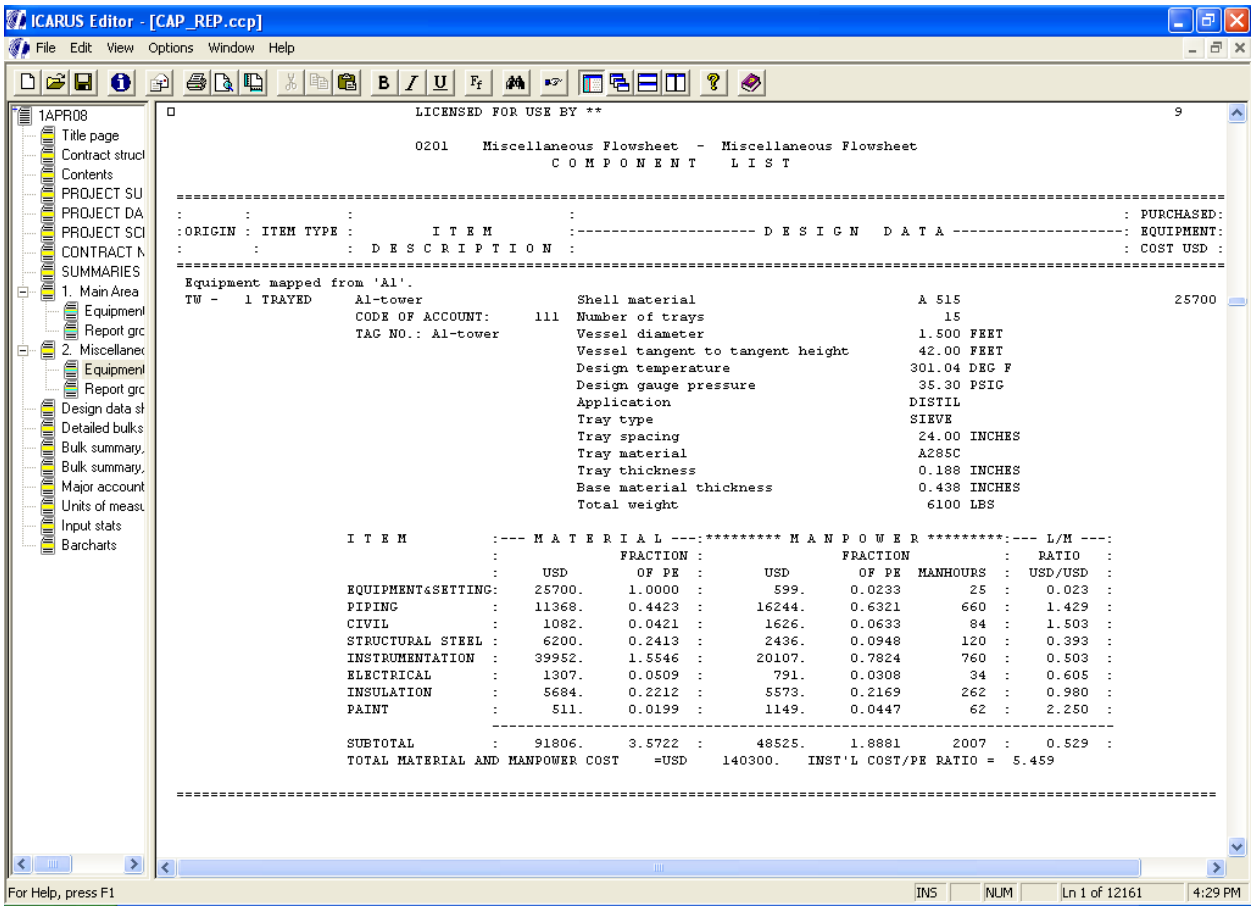
As discussed for the depropanizer, Aspen IPE prepares the *Capital Estimate Report*, MCB.ccp, which contains detailed listings of the items to be procured to install the equipment (classified in the areas of piping, instrumentation, electrical, structural steel, and insulation), estimates of the man-hours required for installation, estimates of the costs, and an installation schedule. Estimates for contractor engineering and indirect costs are listed as well.

The *ICARUS Editor* displays the report in two adjacent windows, with a listing of the major subject headings listed in the left-hand window. Most of this information, though necessary for obtaining accurate cost estimates, is far too detailed for most estimates made in the conceptual design stage, and hence, is normally not printed by process engineers, for whom these notes are intended. Of greatest interest to process engineers, is the information in the following two sections:

1. *Equipment List*
2. *CONTRACTOR NO. 1 PRIME CONTRACTOR*

which are accessed by double-clicking on these titles in the left-hand window. It is recommended that just small portions of the report be printed. This is accomplished by highlighting the desired section and pressing the *Print* button on the toolbar. It is often preferable to print in landscape format.

As shown below, for the absorber, the *List of Equipment and Bulk Material by Area* portion of the report is displayed when the *Equipment List* is accessed. This provides the *Purchased (Equipment & Setting)* and *Installed Direct Costs* (i.e., *Total Material and Manpower Cost* or *Total Direct Materials and Labor Cost*) for each piece of equipment. Furthermore, portions of the complete printed output are provided in Appendix IV of these notes[†].

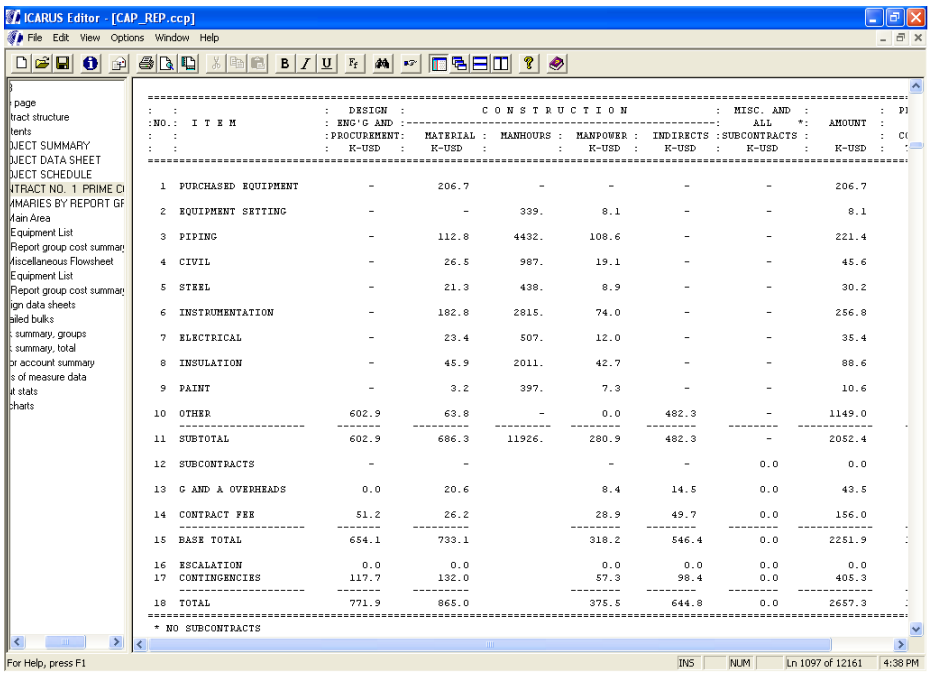

ICARUS Editor - [CAP_REP.ccp]
File Edit View Options Window Help
1APR08
Title page
Contract struct
Contents
PROJECT SU
PROJECT DA
PROJECT SCI
CONTRACT N
SUMMARIES
1. Main Area
Equipment
Report grc
2. Miscellanec
Equipment
Report grc
Design data st
Detailed bulks
Bulk summary,
Bulk summary,
Major account
Units of measu
Input stats
Barcharts
LICENSED FOR USE BY **
9
0201 Miscellaneous Flowsheet - Miscellaneous Flowsheet
C O M P O N E N T L I S T
: PURCHASED:
:ORIGIN : ITEM TYPE : I T E M : D E S I G N D A T A : EQUIPMENT:
: : : D E S C R I P T I O N : : COST USD :
Equipment mapped from 'Al'.
TW - 1 TRAYED Al-tower Shell material A 515 25700
CODE OF ACCOUNT: 111 Number of trays 15
TAG NO.: Al-tower Vessel diameter 1.500 FEET
Vessel tangent to tangent height 42.00 FEET
Design temperature 301.04 DEG F
Design gauge pressure 35.30 PSIG
Application DISTIL
Tray type SIEVE
Tray spacing 24.00 INCHES
Tray material A285C
Tray thickness 0.188 INCHES
Base material thickness 0.438 INCHES
Total weight 6100 LBS
I T E M :--- M A T E R I A L ---:********* M A N P O W E R *********:--- L/M ---:
: FRACTION : FRACTION : RATIO :
: USD OF PE : USD OF PE MANHOURS : USD/USD :
EQUIPMENT&SETTING: 25700. 1.0000 : 599. 0.0233 25 : 0.023 :
PIPING : 11368. 0.4423 : 16244. 0.6321 660 : 1.429 :
CIVIL : 1082. 0.0421 : 1626. 0.0633 84 : 1.503 :
STRUCTURAL STEEL : 6200. 0.2413 : 2436. 0.0948 120 : 0.393 :
INSTRUMENTATION : 39952. 1.5546 : 20107. 0.7824 760 : 0.503 :
ELECTRICAL : 1307. 0.0509 : 791. 0.0308 34 : 0.605 :
INSULATION : 5684. 0.2212 : 5573. 0.2169 262 : 0.980 :
PAINT : 511. 0.0199 : 1149. 0.0447 62 : 2.250 :
SUBTOTAL : 91806. 3.5722 : 48525. 1.8881 2007 : 0.529 :
TOTAL MATERIAL AND MANPOWER COST =USD 140300. INST'L COST/PE RATIO = 5.459
For Help, press F1
INS
NUM
Ln 1 of 12161
4:29 PM

In summary, the equipment sizes, purchase costs, and total material and manpower cost for the MCB separation process are tabulated below:

[†] Note that changing to a 6- or 7-point font is more suitable for printing.

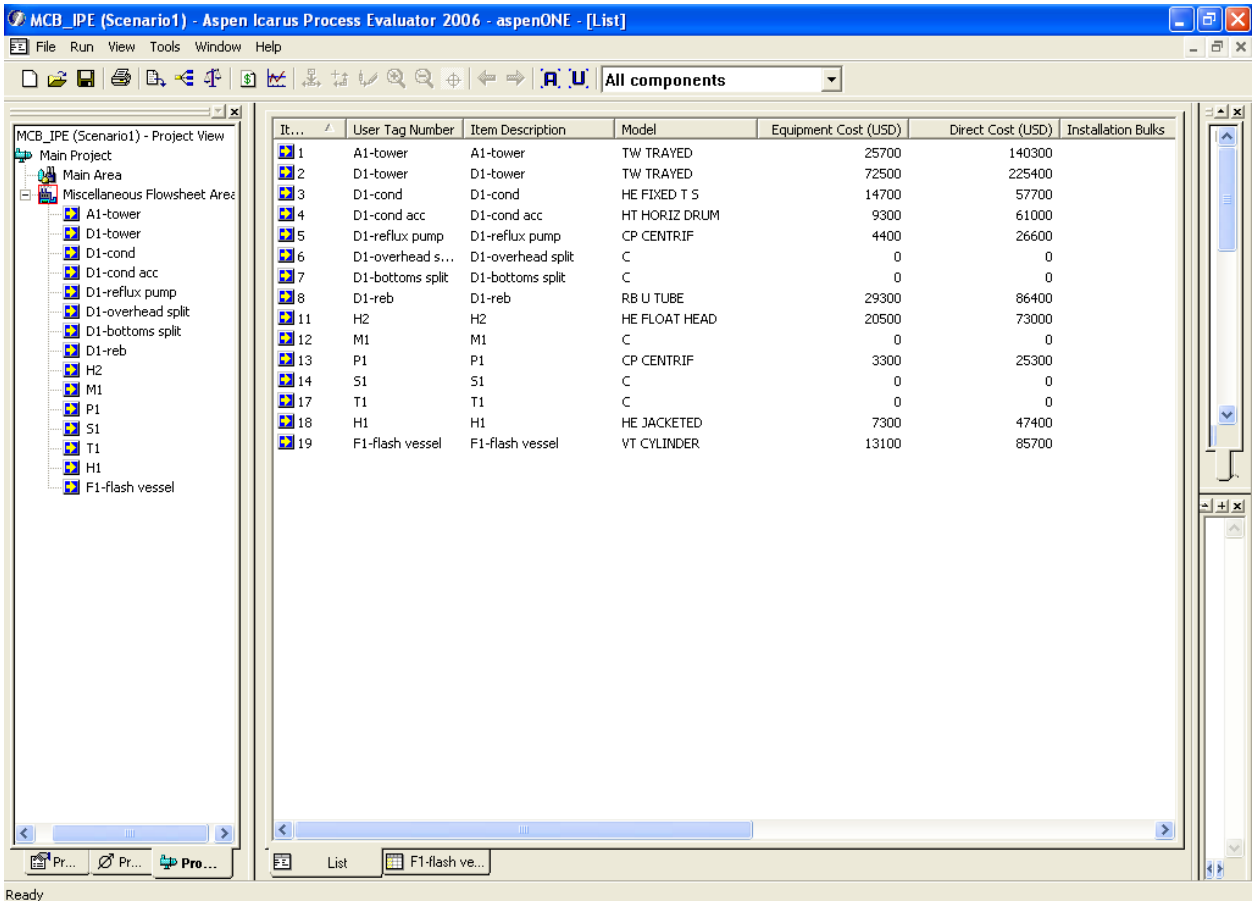
Simulation Unit	Equipment Item	Size	Purchase Cost	Total Material and Manpower Cost
P1	Pump	1.5 Hp	3,300	25,300
A1	Tower	1.5 ft diam. 42 ft height	25,700	140,300
D1	Tower	3.0 ft diam. 72 ft height	72,500	225,400
	Reflux pump	3.0 Hp	4,400	26,600
	Reboiler	918 ft^2	29,300	86,400
	Condenser	154 ft^2	14,700	57,700
	Reflux accumulator	238 gal	9,300	61,000
H1	Heat exchanger	58 ft^2	7,300	47,400
H2	Heat exchanger	196 ft^2	20,500	73,000
F1	Flash vessel	635 gal	13,100	85,700
		TOTAL	$200,100	$828,800

The *Contract Summary* section of the *Capital Estimate Report* is displayed when the *CONTRACT NO. 1 PRIME CONTRACTOR* is accessed. The entries shown below are totals for all of the equipment items in the project. Note that portions of the complete printed output are provided in Appendix IV of these notes.



Note that the entry for the purchased equipment, $206,700, from line 1, is approximately the sum of the entries for the pieces of equipment provided above, $200,100. The difference is due to the *Misc. Item Allowance* ($6,100) and the *Warehouse Spares* ($540). These additional items are in *Code of Accounts* 105 and 107 and appear in the *Code of Accounts Summary* section of the *Capital Estimate Report* (just below the *Contract Summary*.)

The total direct material and manpower costs for construction of the plant are $686,300 and $280,900, as shown in row 11. These sum to $967,200 and include items that cannot be charged to the individual equipment items (e.g., charges for instrument testing, pipe testing, and equipment grounding). Note that the installed costs of the equipment items are displayed on the *List View*:


MCB_IPE (Scenario1) - Aspen Icarus Process Evaluator 2006 - aspenONE - [List]
File Run View Tools Window Help
All components
MCB_IPE (Scenario1) - Project View
Main Project
Main Area
Miscellaneous Flowsheet Area
A1-tower
D1-tower
D1-cond
D1-cond acc
D1-reflux pump
D1-overhead split
D1-bottoms split
D1-reb
H2
M1
P1
S1
T1
H1
F1-flash vessel
It... User Tag Number Item Description Model Equipment Cost (USD) Direct Cost (USD) Installation Bulks
1 A1-tower A1-tower TW TRAYED 25700 140300
2 D1-tower D1-tower TW TRAYED 72500 225400
3 D1-cond D1-cond HE FIXED T S 14700 57700
4 D1-cond acc D1-cond acc HT HORIZ DRUM 9300 61000
5 D1-reflux pump D1-reflux pump CP CENTRIF 4400 26600
6 D1-overhead s... D1-overhead split C 0 0
7 D1-bottoms split D1-bottoms split C 0 0
8 D1-reb D1-reb RB U TUBE 29300 86400
11 H2 H2 HE FLOAT HEAD 20500 73000
12 M1 M1 C 0 0
13 P1 P1 CP CENTRIF 3300 25300
14 S1 S1 C 0 0
17 T1 T1 C 0 0
18 H1 H1 HE JACKETED 7300 47400
19 F1-flash vessel F1-flash vessel VT CYLINDER 13100 85700
List
F1-flash ve...
Ready

These direct (installed) costs sum to $828,800; that is, $138,400 less than the total direct cost of materials and manpower for installation of the plant, $967,200. This *Installed Direct Cost*, C_{DI}, is referred to in Chapter 22 of the textbook as the *Total Direct Materials and Labor Cost*, C_{DML}. Finally, the materials and manpower items that cannot be charged to the individual equipment items are displayed in the *Area Bulk Report* within the *Capital Estimate Report*:

A R E A B U L K R E P O R T

ORIGIN	ITEM SYMBOL	DESCRIPTION / DESIGN DATA		MATERIAL COST-USD	MANPOWER MANHOURS	MANPOWER COST-USD	TOTAL DIRECT COST-USD
AREA		MISC CONCRETE ITEMS		918.	173	3354.	4272.
AREA		PIPE TESTING		0.	335	8381.	8381.
GRADE		UNPAVED AREA		8552.	127	2997.	11549.
		Area length	50.000 FEET				
		Area width	50.000 FEET				
AREA		INSTRUMENT TESTING		0.	179	4672.	4672.
AREA		INSTR. RUNS,TRAYS,JBOX.		4132.	81	1943.	6075.
AREA		EQUIPMENT GROUNDING		419.	23	519.	938.
AREA		PILED FOUNDATION		16974.	131	2575.	19549.
		Number of piles	22				
AREA		ELECTRICAL TESTING		0.	22	548.	548.
AREA		ROTATING EQP SPARE PARTS		540.	0	0.	540.

These additional costs sum to approximately $56,500. Together with the *Other* item on line 10 of the *Contract Summary*, $63,800, and *Code of Accounts* item 105, for equipment contingencies to allow for design changes, $6,100, these sum to approximately $126,400 (which, for profitability analysis in the conceptual design stage, is sufficiently close to $138,400, the difference reported above).

Returning to the *Contract Summary*, material and manpower costs associated with *G and A (General and Administrative) Overheads*, $20,600 and $8,400, are obtained from line 13, and material and manpower charges associated with *Contract Fees*, $26,200 and $28,900, from line 14. These sum to $84,100. The contractor engineering and indirect costs are in row 15, *BASE TOTAL*, in the first column, under *DESIGN ENG'G AND PROCUREMENT K-USD*, and in the fifth COLUMN, under *CONSTRUCTION INDIRECTS K-USD*. These are:

Contractor Engineering Costs	$654,100
Indirect Costs	$546,400

Together with the fees for materials and manpower *G and A Overheads* and *Contract Fees*, these are added to the total direct installed equipment costs, C_{DI}, to give the *IBL Total Bare Module Cost*, C_{TBM}.

Finally, all of the Aspen IPE results can be reproduced using the MCB folder (in the ASPEN folder on the Wiley web site for this book) from within Aspen IPE.

Total Permanent Investment

The total permanent investment is computed by the spreadsheet, Profitability Analysis-2.0.xls, discussed in Section 23.8 of the textbook. When using the Aspen IPE option, the user enters:

Total Direct Materials and Labor Costs	$828,800
Material and Labor G&A Overhead and Contractor Fees	84,100
Contractor Engineering Costs	654,100
Indirect Costs	546,400

ASPEN IPE FOLDERS AND FILES

When a new project is created within Aspen IPE, a folder having the project name (e.g., DEC3) is created in the \Program Files\AspenTech\Aspen Icarus 2006\ic_cache\Projects\YourProjectName folder. As work with Aspen IPE proceeds, various files are created and stored in this project folder; for example, the DEC3.ccp file, which contains the *Capital Estimate Report* for the depropanizer. Note that these files are deleted when the project is closed. When closed, projects are stored in compact backup files (.izp and .szp) in the \Program Files\AspenTech\Aspen Icarus 2006\Data\Archives_IPE\YourProjectName folder.

When returning to work with Aspen IPE, using the *File* pulldown menu, open the folder having the appropriate project name. This produces the *Open an IPE Project* dialog box. Select the *Project Name* and press the *OK* button. This produces the *Process/Project View* window; that is, the IPE *Main* window.

When working in the *Process/Project View* window, to examine any portion of the *Capital Estimate Report* (which is automatically stored in your *Projects* folder after it has been generated), press the *Capital costs* button ($) on the toolbar. This produces the *Select Report Type To View* dialog box. Select one of the two options to have Aspen IPE display the capital cost report as an HTML file or in the ICARUS Editor. Then, press *OK*. Note that when more than one report file exists, the *Select Capital Cost Report File* dialog box is produced, from which the appropriate report file is selected. This produces the *Capital Estimate Report.*

REFERENCES

Aspen Technology, Inc., *Aspen IPE 2006 User Guide*, 2006.

Lewin, D. R., W. D. Seider, J. D. Seader, E. Dassau, J. Golbert, D. N. Goldberg, M. J. Fucci, and R. B. Nathanson, CD-ROM, *Using Process Simulators in Chemical Engineering: A Multimedia Guide for the Core Curriculum*, Version 2.0, Wiley, 2003.

Seider, W. D., J. D. Seader, and D. R. Lewin, *Process Design Principles: Synthesis, Analysis, and Evaluation*, Wiley, 1999.

Seider, W. D., J. D. Seader, and D. R. Lewin, *Product and Process Design Principles: Synthesis, Analysis, and Evaluation*, Second Edition, Wiley, 2004.

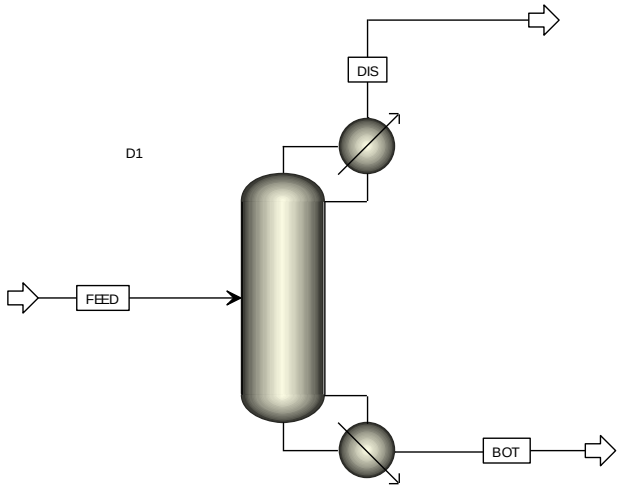
Smith, J. M., H. C. Van Ness, and M. M. Abbott, *Introduction to Chemical Engineering Thermodynamics*, Sixth Edition, McGraw-Hill, 2001.

APPENDIX I

DEPROPANIZER

ASPEN PLUS Report

ASPEN PLUS Flowsheet - simulation results can be reproduced using the file RADFRAC.bkp in the ASPEN folder on the Wiley web site.



ASPEN PLUS Program

```
IN-UNITS ENG
DEF-STREAMS CONVEN ALL
DATABANKS PURE93  / AQUEOUS  / SOLIDS  / INORGANIC  /  &
        NOASPENPCD
PROP-SOURCES PURE93  / AQUEOUS  / SOLIDS  / INORGANIC
COMPONENTS
    C2H6 C2H6 /
    C3H8 C3H8 /
    C4H10-1 C4H10-1 /
    C5H12-1 C5H12-1 /
    C6H14-1 C6H14-1
FLOWSHEET
    BLOCK D1 IN=FEED OUT=DIS BOT
PROPERTIES RK-SOAVE
USER-PROPS DRUSR2 1 2 3
PROP-DATA RKSKIJ-1
    IN-UNITS ENG
    PROP-LIST RKSKIJ
    BPVAL C2H6 C3H8 -2.2000000E-3
    BPVAL C2H6 C4H10-1 6.70000000E-3
    BPVAL C2H6 C5H12-1 5.60000000E-3
    BPVAL C2H6 C6H14-1 -.0156000000
    BPVAL C3H8 C4H10-1 0.0
    BPVAL C3H8 C5H12-1 .0233000000
    BPVAL C3H8 C6H14-1 -2.2000000E-3
    BPVAL C3H8 C2H6 -2.2000000E-3
    BPVAL C4H10-1 C3H8 0.0
    BPVAL C4H10-1 C5H12-1 .0204000000
    BPVAL C4H10-1 C6H14-1 -.0111000000
    BPVAL C4H10-1 C2H6 6.70000000E-3
    BPVAL C5H12-1 C3H8 .0233000000
    BPVAL C5H12-1 C4H10-1 .0204000000
    BPVAL C5H12-1 C2H6 5.60000000E-3
STREAM FEED
    SUBSTREAM MIXED TEMP=225 PRES=250
    MOLE-FLOW C2H6 30 / C3H8 200 / C4H10-1 370 / C5H12-1  &
        350 / C6H14-1 50
```

```
BLOCK D1 RADFRAC
    PARAM NSTAGE=14
    COL-CONFIG CONDENSER=PARTIAL-V
    FEEDS FEED 7
    PRODUCTS BOT 14 L / DIS 1 V
    P-SPEC 1 248
    COL-SPECS D:F=.226 DP-COL=4 MOLE-RR=6.06
    SPEC 1 MOLE-FLOW 191 PHASE=V STAGE=1 COMPS=C3H8
    VARY 1 MOLE-RR 3 9
STREAM-REPOR MOLEFLOW
```

Stream Variables

```
BOT DIS FEED
 ------------

 STREAM ID                BOT        DIS        FEED
 FROM :                   D1         D1         ----
 TO   :                   ----       ----       D1

 SUBSTREAM: MIXED
 PHASE:                   LIQUID     VAPOR      MIXED
 COMPONENTS: LBMOL/HR
   C2H6                3.5935-03    29.9964    30.0000
   C3H8                   9.0000   191.0000   200.0000
   C4H10-1              365.0282     4.9718   370.0000
   C5H12-1              349.9682  3.1817-02   350.0000
   C6H14-1               50.0000  5.6799-06    50.0000
 TOTAL FLOW:
   LBMOL/HR             774.0000   226.0000  1000.0000
   LB/HR               5.1173+04  9615.6886  6.0789+04
   CUFT/HR             1757.1876  4228.0955  7798.4407
 STATE VARIABLES:
   TEMP   F             260.8017   115.0748   225.0000
   PRES   PSI           252.0000   248.0000   250.0000
   VFRAC                  0.0        1.0000     0.2831
   LFRAC                  1.0000     0.0        0.7169
   SFRAC                  0.0        0.0        0.0
 ENTHALPY:
   BTU/LBMOL          -6.1678+04 -4.4212+04 -5.7856+04
   BTU/LB              -932.8868 -1039.1178  -951.7619
   BTU/HR             -4.7738+07 -9.9918+06 -5.7856+07
 ENTROPY:
   BTU/LBMOL-R         -105.9894   -66.3064   -96.4772
   BTU/LB-R              -1.6031    -1.5584    -1.5871
 DENSITY:
   LBMOL/CUFT             0.4405  5.3452-02     0.1282
   LB/CUFT               29.1220     2.2742     7.7950
 AVG MW                  66.1148    42.5473    60.7885
```

Process Unit Output

```
BLOCK:  D1       MODEL: RADFRAC
 ------------------------------
    INLETS   - FEED     STAGE   7
    OUTLETS  - DIS      STAGE   1
               BOT      STAGE  14
    PROPERTY OPTION SET:   RK-SOAVE  STANDARD RKS EQUATION OF STATE
```

*** MASS AND ENERGY BALANCE ***

	IN	OUT	RELATIVE DIFF.
TOTAL BALANCE			
MOLE(LBMOL/HR)	1000.00	1000.00	-0.113687E-15
MASS(LB/HR)	60788.5	60788.5	-0.263325E-14
ENTHALPY(BTU/HR)	-0.578562E+08	-0.577303E+08	-0.217615E-02

**** INPUT DATA ****

NUMBER OF STAGES	14
ALGORITHM OPTION	STANDARD
ABSORBER OPTION	NO
INITIALIZATION OPTION	STANDARD
HYDRAULIC PARAMETER CALCULATIONS	NO
INSIDE LOOP CONVERGENCE METHOD	BROYDEN
DESIGN SPECIFICATION METHOD	NESTED
MAXIMUM NO. OF OUTSIDE LOOP ITERATIONS	25
MAXIMUM NO. OF INSIDE LOOP ITERATIONS	10
MAXIMUM NUMBER OF FLASH ITERATIONS	50
FLASH TOLERANCE	0.000100000
OUTSIDE LOOP CONVERGENCE TOLERANCE	0.000100000

**** COL-SPECS ****

MOLAR VAPOR DIST / TOTAL DIST	1.00000
MOLAR REFLUX RATIO	6.06000
DISTILLATE TO FEED RATIO	0.22600

**** RESULTS ****

*** COMPONENT SPLIT FRACTIONS ***

	OUTLET STREAMS	
	DIS	BOT
COMPONENT:		
C2H6	.99988	.11978E-03
C3H8	.95500	.45000E-01
C4H10-1	.13437E-01	.98656
C5H12-1	.90906E-04	.99991
C6H14-1	.11360E-06	1.0000

*** SUMMARY OF KEY RESULTS ***

TOP STAGE TEMPERATURE	F	115.075
BOTTOM STAGE TEMPERATURE	F	260.802
TOP STAGE LIQUID FLOW	LBMOL/HR	2,006.29
BOTTOM STAGE LIQUID FLOW	LBMOL/HR	774.000
TOP STAGE VAPOR FLOW	LBMOL/HR	226.000
BOTTOM STAGE VAPOR FLOW	LBMOL/HR	1,655.79
MOLAR REFLUX RATIO		8.87737
MOLAR BOILUP RATIO		2.13927
CONDENSER DUTY (W/O SUBCOOL)	BTU/HR	-0.115854+08
REBOILER DUTY	BTU/HR	0.117112+08

**** PROFILES ****

NOTE REPORTED VALUES FOR STAGE LIQUID AND VAPOR RATES ARE THE FLOWS FROM THE STAGE EXCLUDING ANY SIDE PRODUCT. FOR THE FIRST STAGE, THE REPORTED VAPOR FLOW IS THE VAPOR DISTILLATE FLOW. FOR THE LAST STAGE, THE REPORTED LIQUID FLOW IS THE LIQUID BOTTOMS FLOW.

STAGE	TEMPERATURE F	PRESSURE PSI	ENTHALPY BTU/LBMOL LIQUID	VAPOR	HEAT DUTY BTU/HR
1	115.07	248.00	-50783.	-44212.	-.11585+08
2	125.28	248.31	-51581.	-44928.	
3	136.57	248.62	-52692.	-45507.	
5	170.39	249.23	-55843.	-47215.	
6	190.65	249.54	-57560.	-48372.	
7	209.38	249.85	-59032.	-49521.	
8	217.28	250.15	-59293.	-50212.	
11	235.62	251.08	-59970.	-51780.	
12	241.42	251.38	-60295.	-52207.	
13	248.99	251.69	-60816.	-52686.	
14	260.80	252.00	-61678.	-53340.	.11711+08

STAGE	FLOW RATE LBMOL/HR LIQUID	VAPOR	FEED RATE LBMOL/HR LIQUID	VAPOR	MIXED	PRODUCT RATE LBMOL/HR LIQUID	VAPOR
1	2006.	226.0					226.0000
2	1955.	2232.					
3	1864.	2181.					
5	1677.	1989.					
6	1600.	1903.		283.3846			
7	2334.	1542.	716.6153				
8	2372.	1560.					
11	2453.	1661.					
12	2454.	1679.					
13	2430.	1680.					
14	774.0	1656.				774.0000	

**** MASS FLOW PROFILES ****

STAGE	FLOW RATE LB/HR LIQUID	VAPOR	FEED RATE LB/HR LIQUID	VAPOR	MIXED	PRODUCT RATE LB/HR LIQUID	VAPOR
1	0.8848E+05	9616.					9615.6886
2	0.8897E+05	0.9810E+05					
3	0.8829E+05	0.9859E+05					
5	0.8877E+05	0.9759E+05					
6	0.8996E+05	0.9838E+05		.15740+05			
7	0.1382E+06	0.8384E+05	.45048+05				
8	0.1425E+06	0.8706E+05					
11	0.1523E+06	0.9845E+05					
12	0.1544E+06	0.1012E+06					
13	0.1558E+06	0.1032E+06					
14	0.5117E+05	0.1047E+06				.51173+05	

**** MOLE-X-PROFILE ****

STAGE	C2H6	C3H8	C4H10-1	C5H12-1	C6H14-1
1	0.57253E-01	0.88576	0.56268E-01	0.71663E-03	0.36784E-06
2	0.26424E-01	0.84979	0.12085	0.29316E-02	0.41399E-05
3	0.14274E-01	0.74938	0.22597	0.10340E-01	0.39505E-04
5	0.75715E-02	0.43455	0.48005	0.75943E-01	0.18785E-02
6	0.66748E-02	0.29446	0.53451	0.15547	0.88845E-02
7	0.40998E-02	0.20293	0.52813	0.23898	0.25864E-01
8	0.16827E-02	0.15681	0.56948	0.24609	0.25942E-01
11	0.10271E-03	0.56172E-01	0.63050	0.28601	0.27216E-01
12	0.38791E-04	0.36411E-01	0.61454	0.31913	0.29880E-01
13	0.14072E-04	0.21933E-01	0.56594	0.37366	0.38453E-01
14	0.46428E-05	0.11628E-01	0.47161	0.45216	0.64599E-01

**** MOLE-Y-PROFILE ****

STAGE	C2H6	C3H8	C4H10-1	C5H12-1	C6H14-1
1	0.13273	0.84513	0.21999E-01	0.14078E-03	0.25132E-07
2	0.64894E-01	0.88165	0.52798E-01	0.65833E-03	0.33314E-06
3	0.37438E-01	0.84931	0.11061	0.26424E-02	0.37136E-05
5	0.23512E-01	0.62700	0.32189	0.27326E-01	0.27279E-03
6	0.22436E-01	0.48332	0.42565	0.66941E-01	0.16554E-02
7	0.14670E-01	0.37152	0.48748	0.12031	0.60259E-02
8	0.61322E-02	0.29788	0.55617	0.13318	0.66399E-02
11	0.38744E-03	0.11540	0.69553	0.18013	0.85532E-02
12	0.14792E-03	0.76709E-01	0.70375	0.20941	0.99812E-02
13	0.54526E-04	0.47830E-01	0.68040	0.25783	0.13882E-01
14	0.18479E-04	0.26750E-01	0.61003	0.33697	0.26231E-01

APPENDIX II

DESIGN CRITERIA SPECIFICATIONS

Name	Unit	Item
Common		
Design Pressure		*Table 1*
Design Temperature		*Table 2*
Pumps		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Pump Overdesign Factor		1.1
Compressors		
Design Pressure		*Table 1*
Design Temperature		*Table 4*
Driver Type		Motor
Heat Exchangers		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Apply 2/3 Rule for Design Pressure		YES
Heat Ex Area Min. Overdesign Factor		1.15
Air Cooler Inlet Temperature	°F	77
Air Cooler Exit Temperature	°F	120
Plate - Fin | Launch MUSE		No
Furnace | Fractional Efficiency		0.9
Furnace | Fuel Heating Value	Btu/lb	840
Towers		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Vapor Disengagement Height	ft	6
Bottom Sump Height	ft	8
R/R Minimum		1.35
Towers | Packed		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Packing Type		Random
Packing Factor for Packings		55
Packed Tower Derating Factor		1
Packed Tower Flooding Factor		0.6
HETP	ft	3
Packed Section Height	ft	10
Surface Area Per Unit Volume	ft^2/ft^3	75
Towers | Trayed		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Tray Spacing	in	24
Trayed Tower Flooding Factor		0.8
Foaming Tendency		Moderate
Trayed Tower Derating Factor		1
Relative Vol. of Key Components		1.5
Tray Efficiency		1

Table 1 Design Pressure (*DP*)
Pumps, Heat Exch's, Towers, etc
DP=OP(1+*A*/100)+*B*

Operating Pressures	From (psia)	To (psia)	*A*	*B*
Range 1	0	15	-100	15
Range 2	15	50	-100	50
Range 3	50	265	0	25
Range 4	265	1015	0	50
Range 5	1015		5	0

Table 2 Design Temp. (*DT*)
Common Items
DT=OT(1+*A*/100)+*B*

Operating Temps	From (°F)	To (°F)	*A*	*B* (°F)
Range 1	0	15	-100	15
Range 2	15	50	-100	50
Range 3	50	265	0	25
Range 4	265	1015	0	50
Range 5	1015		5	0

Table 3 Design Temp. (*DT*)
Pumps, Heat Exch's, Towers, etc
DT=OT(1+*A*/100)+*B*

Operating Temps	From (°F)	To (°F)	*A*	*B* (°F)
Range 1	-459.7	32	0	-50
Range 2	32	70	-100	70
Range 3	70	200	-100	250
Range 4	200	600	0	50
Range 5	600		0	50

Table 4 Design Temp. (*DT*)
Compressors
DT=OT(1+*A*/100)+*B*

Operating Temps	From (°F)	To (°F)	*A*	*B* (°F)
Range 1	-459.7	32	0	0
Range 2	32	70	0	0
Range 3	70	200	0	0
Range 4	200	600	0	0
Range 5	600		0	0

OT = Operating Temperature
OP = Operating Pressure

Name	Unit	Item
Towers | Configurations		
Precooler Outlet Fluid Temperature	°F	
Process Fluid Condensation Temperature	°F	
Ratio of Recycle to (Ovhdliqprod+Reflux)		10
SC Trim Splitter Flow Split Ratio		0.2
Ratio of SC Trim Duty to Overall Duty		0.1
Ratio of Precooler Duty to Overall Duty		0.5
Vessels		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Residence Time	min	5
Process Vessel Height to Diameter Ratio		3
Minimum Vessel Diameter	ft	3
Vapor/Liquid Separator Sizing Method		Liquid Entrainment Model
Average Liquid Particle Diameter	in	0.15
Design Factor Multiplier for Disengagement Velocity		0.5
Separation Factor		
Vessels | Agitated		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Minimum Disengagement Height	ft	4
Residence Time	min	5
Agitator Type		Mech-Seal
Vessels | Storage		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Number of Holding Days		1
Holding Hours in a Day		24
Storage Vessel Height to Diameter Ratio		0.4
Vapor Free Space (% of Total Storage Vessel Vol)		5
Vessels | Horizontal		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Residence Time	min	5
Vapor Area / Cross Sectional Area		0.2
Separation Factor Multiplier		1.25
Minimum Boot Length	ft	3
Minimum Boot Diameter	ft	2
Boot Leg Liquid Velocity	ft/min	0.5

Name	Unit	Item
Vessels | *Vertical*		
Design Pressure		*Table 1*
Design Temperature		*Table 3*
Residence Time	min	5
Minimum Disengagement Height	ft	4
Minimum Height above Mist Eliminator	ft	1
Height of Mist Eliminator	ft	0.5
Minimum Ht. Btw Low and High Liq Lev Taps	ft	4
Ht. Btw Inlet Nozzle and High Liq Level Tap	ft	2
Ht. Btw Low Level Liquid Tap and Tang Line	ft	0.5
Miscellaneous		
Vibrating Screen Feed Material		Wood
Cyclone Inlet Linear Velocity	ft/sec	150
Flash | *Configurations*		
Delta T across Recirculation HX	°F	10
Delta P across Recirculation Pump	psi	5

APPENDIX III

ASPEN IPE CAPITAL ESTIMATE REPORT FOR THE DEPROPANIZER

Selected portions of the

List of Equipment and Bulk Material by Area

and the

Contract Summary

Depropanizer Without the Reboiler Pump (see DEC3 Folder)

C O N T R A C T S U M M A R Y

PRIME CONTRACTOR (CONTRACT NO. 1)

NO.	ITEM	DESIGN ENG'G AND PROCUREMENT K-USD	CONSTRUCTION MATERIAL K-USD	CONSTRUCTION MANHOURS	CONSTRUCTION MANPOWER K-USD	CONSTRUCTION INDIRECTS K-USD	MISC. AND ALL SUBCONTRACTS K-USD	AMOUNT K-USD	PERCENT OF CONTRACT TOTAL
1	PURCHASED EQUIPMENT	-	378.6	-	-	-	-	378.6	19.6
2	EQUIPMENT SETTING	-	-	272.	6.5	-	-	6.5	0.3
3	PIPING	-	158.0	2893.	70.7	-	-	228.7	11.8
4	CIVIL	-	18.8	717.	13.9	-	-	32.7	1.7
5	STEEL	-	9.6	218.	4.4	-	-	14.1	0.7
6	INSTRUMENTATION	-	104.9	1496.	39.3	-	-	144.2	7.5
7	ELECTRICAL	-	19.9	380.	9.0	-	-	28.9	1.5
8	INSULATION	-	35.3	1346.	28.5	-	-	63.9	3.3
9	PAINT	-	3.6	398.	7.3	-	-	10.9	0.6
10	OTHER	413.0	74.7	-	0.0	372.4	-	860.1	44.4
11	SUBTOTAL	413.0	803.5	7720.	179.7	372.4	-	1768.6	91.4
12	SUBCONTRACTS	-	-		-	-	0.0	0.0	0.0
13	G AND A OVERHEADS	0.0	24.1		5.4	11.2	0.0	40.7	2.1
14	CONTRACT FEE	38.0	28.1		19.4	40.3	0.0	125.8	6.5
15	BASE TOTAL	451.0	855.7		204.5	423.8	0.0	1935.1	100.0
16	ESCALATION	0.0	0.0		0.0	0.0	0.0	0.0	0.0
17	CONTINGENCIES	81.2	154.0		36.8	76.3	0.0	348.3	18.0
18	TOTAL	532.2	1009.7		241.4	500.1	0.0	2283.4	118.0

* NO SUBCONTRACTS

C O M P O N E N T L I S T

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'D1'.					
HT - 3	HORIZ DRUM	D1-cond acc	Shell material	A 515	25700
		CODE OF ACCOUNT: 114	Liquid volume	2350.23 GALLONS	
		TAG NO.: D1-cond acc	Vessel diameter	5.000 FEET	
			Vessel tangent to tangent length	16.00 FEET	
			Design temperature	250.00 DEG F	
			Design gauge pressure	258.30 PSIG	
			Application	CONT	
			Base material thickness	0.625 INCHES	
			Total weight	9600 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	25700.	1.0000	693.	0.0270	29	0.027
PIPING	21078.	0.8202	10716.	0.4170	439	0.508
CIVIL	1892.	0.0736	2280.	0.0887	118	1.205
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	24219.	0.9424	4428.	0.1723	168	0.183
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	0.	0.0000	0.	0.0000	0	0.000
PAINT	1181.	0.0460	2004.	0.0780	108	1.696
SUBTOTAL	74071.	2.8821	20122.	0.7830	862	0.272

TOTAL MATERIAL AND MANPOWER COST =USD 94200. INST'L COST/PE RATIO = 3.665

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'D1'.					
CP - 4	CENTRIF	D1-reflux pump	Casing material	CS	7100
		CODE OF ACCOUNT: 161	Liquid flow rate	401.99 GPM	
		TAG NO.: D1-reflux pu	Fluid head	225.00 FEET	
			Design temperature	250.00 DEG F	
			Speed	3600.00 RPM	
			Driver power	20.00 HP	
			Fluid viscosity	0.0775 CPOISE	
			Design gauge pressure	258.30 PSIG	
			Driver type	MOTOR	
			Seal type	SNGL	
			Total weight	710 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	7100.	1.0000	618.	0.0870	26	0.087
PIPING	10899.	1.5351	5131.	0.7227	210	0.471
CIVIL	315.	0.0444	796.	0.1121	41	2.528
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	7051.	0.9931	2081.	0.2931	80	0.295
ELECTRICAL	679.	0.0957	1015.	0.1430	42	1.494
INSULATION	2310.	0.3253	2089.	0.2942	98	0.904
PAINT	176.	0.0248	411.	0.0579	22	2.336
SUBTOTAL	28530.	4.0184	12141.	1.7100	519	0.426

TOTAL MATERIAL AND MANPOWER COST =USD 40700. INST'L COST/PE RATIO = 5.732

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'D1'.					
QUOTE EQP- 5		D1-overhead split	Number of identical items	1	0
		CODE OF ACCOUNT: 100			
		TAG NO.: D1-overhead			

:ORIGIN	ITEM TYPE	ITEM DESCRIPTION		DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.						
QUOTE EQP- 6		D1-bottoms split CODE OF ACCOUNT: 100 TAG NO.: D1-bottoms s	Number of identical items	1		0

Equipment mapped from 'D1'.

RB - 7	KETTLE	D1-reb CODE OF ACCOUNT: 262 TAG NO.: D1-reb	Tube material	A 214		68100
			Heat transfer area	3579.55	SF	
			Shell material	A285C		
			TEMA type	BKT		
			Shell design gauge pressure	262.00	PSIG	
			Shell design temperature	310.80	DEG F	
			Shell diameter	54.00	INCHES	
			Shell length	25.00	FEET	
			Tube port diameter	36.00	INCHES	
			Tube design gauge pressure	169.77	PSIG	
			Tube design temperature	331.00	DEG F	
			Tube outside diameter	1.000	INCHES	
			Tube length extended	20.00	FEET	
			Total weight	34300	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	68100.	1.0000	1266.	0.0186	52	0.019
PIPING	15248.	0.2239	10330.	0.1517	422	0.677
CIVIL	1711.	0.0251	2113.	0.0310	110	1.235
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	15974.	0.2346	5682.	0.0834	217	0.356
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	6674.	0.0980	6058.	0.0890	286	0.908
PAINT	314.	0.0046	746.	0.0109	40	2.373
SUBTOTAL	108021.	1.5862	26195.	0.3847	1127	0.243

TOTAL MATERIAL AND MANPOWER COST =USD 134200. INST'L COST/PE RATIO = 1.971

:ORIGIN	ITEM TYPE	ITEM DESCRIPTION		DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.						
TW - 1	TRAYED	D1-tower CODE OF ACCOUNT: 111 TAG NO.: D1-tower	Shell material	A 515		86300
			Number of trays	15		
			Vessel diameter	5.000	FEET	
			Vessel tangent to tangent height	42.00	FEET	
			Design temperature	310.80	DEG F	
			Design gauge pressure	262.30	PSIG	
			Application	DISTIL		
			Tray type	SIEVE		
			Tray spacing	24.00	INCHES	
			Tray material	A285C		
			Tray thickness	0.188	INCHES	
			Base material thickness	0.625	INCHES	
			Total weight	31700	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	86300.	1.0000	2208.	0.0256	92	0.026
PIPING	34421.	0.3989	18020.	0.2088	737	0.524
CIVIL	1875.	0.0217	2421.	0.0280	126	1.291
STRUCTURAL STEEL	9649.	0.1118	4427.	0.0513	218	0.459
INSTRUMENTATION	43929.	0.5090	20107.	0.2330	760	0.458
ELECTRICAL	1903.	0.0221	1034.	0.0120	45	0.543
INSULATION	11769.	0.1364	9654.	0.1119	455	0.820
PAINT	931.	0.0108	1948.	0.0226	106	2.091
SUBTOTAL	190778.	2.2106	59818.	0.6931	2539	0.314

TOTAL MATERIAL AND MANPOWER COST =USD 250600. INST'L COST/PE RATIO = 2.904

:ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.					
HE - 2	FLOAT HEAD	D1-cond	Tube material	A 214	179800
		CODE OF ACCOUNT: 261	Number of shells	2	
		TAG NO.: D1-cond	Area per shell	5551.00 SF	
			Shell material	A285C	
			TEMA type	BES	
			Shell design gauge pressure	258.61 PSIG	
			Shell design temperature	250.00 DEG F	
			Shell diameter	46.00 INCHES	
			Shell length	23.00 FEET	
			Tube design gauge pressure	167.51 PSIG	
			Tube design temperature	250.00 DEG F	
			Tube outside diameter	1.000 INCHES	
			Tube length extended	20.00 FEET	
			Total weight	89400 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	179800.	1.0000	1760.	0.0098	73	0.010
PIPING	76345.	0.4246	21423.	0.1191	881	0.281
CIVIL	1474.	0.0082	1904.	0.0106	99	1.292
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	11546.	0.0642	3342.	0.0186	129	0.289
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	14567.	0.0810	10748.	0.0598	506	0.738
PAINT	984.	0.0055	2238.	0.0124	121	2.274
SUBTOTAL	284716.	1.5835	41415.	0.2303	1809	0.145

TOTAL MATERIAL AND MANPOWER COST =USD 326100. INST'L COST/PE RATIO = 1.814

A R E A B U L K R E P O R T

ORIGIN	ITEM SYMBOL	DESCRIPTION / DESIGN DATA		MATERIAL COST-USD	MANPOWER MANHOURS	MANPOWER COST-USD	TOTAL DIRECT COST-USD
AREA		MISC CONCRETE ITEMS		743.	140	2718.	3461.
AREA		PIPE TESTING		0.	204	5112.	5112.
GRADE		UNPAVED AREA		8552.	127	2997.	11549.
		Area length	50.000 FEET				
		Area width	50.000 FEET				
AREA		INSTRUMENT TESTING		0.	95	2474.	2474.
AREA		INSTR. RUNS,TRAYS,JBOX.		2200.	49	1150.	3350.
AREA		EQUIPMENT GROUNDING		209.	11	259.	468.
AREA		PILED FOUNDATION		10802.	83	1638.	12440.
		Number of piles	14				
AREA		ELECTRICAL TESTING		0.	16	389.	389.
AREA		ROTATING EQP SPARE PARTS		500.	0	0.	500.

Depropanizer With the Reboiler Pump (see DEC3RP Folder)

C O N T R A C T S U M M A R Y

PRIME CONTRACTOR (CONTRACT NO. 1)

NO.	ITEM	DESIGN ENG'G AND PROCUREMENT K-USD	CONSTRUCTION MATERIAL K-USD	CONSTRUCTION MANHOURS	CONSTRUCTION MANPOWER K-USD	CONSTRUCTION INDIRECTS K-USD	MISC. AND ALL SUBCONTRACTS K-USD	AMOUNT K-USD	PERCENT OF CONTRACT TOTAL
1	PURCHASED EQUIPMENT	-	353.8	-	-	-	-	353.8	17.6
2	EQUIPMENT SETTING	-	-	284.	6.8	-	-	6.8	0.3
3	PIPING	-	174.1	3154.	77.1	-	-	251.2	12.5
4	CIVIL	-	18.4	712.	13.8	-	-	32.1	1.6
5	STEEL	-	9.6	218.	4.4	-	-	14.1	0.7
6	INSTRUMENTATION	-	112.0	1581.	41.5	-	-	153.5	7.6
7	ELECTRICAL	-	29.2	565.	13.4	-	-	42.5	2.1
8	INSULATION	-	37.6	1409.	29.9	-	-	67.5	3.4
9	PAINT	-	3.8	428.	7.9	-	-	11.7	0.6
10	OTHER	445.3	75.7	-	0.0	385.4	-	906.4	45.0
11	SUBTOTAL	445.3	814.2	8351.	194.8	385.4	-	1839.7	91.4
12	SUBCONTRACTS	-	-		-	-	0.0	0.0	0.0
13	G AND A OVERHEADS	0.0	24.4		5.8	11.6	0.0	41.8	2.1
14	CONTRACT FEE	40.1	28.5		20.9	41.3	0.0	130.7	6.5
15	BASE TOTAL	485.4	867.1		221.5	438.2	0.0	2012.3	100.0
16	ESCALATION	0.0	0.0		0.0	0.0	0.0	0.0	0.0
17	CONTINGENCIES	87.4	156.1		39.9	78.9	0.0	362.2	18.0
18	TOTAL	572.7	1023.2		261.4	517.1	0.0	2374.5	118.0

* NO SUBCONTRACTS

C O M P O N E N T L I S T

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA			PURCHASED EQUIPMENT COST USD
CP - 8	CENTRIF	Reboiler Pump	Casing material	CS		8100
		CODE OF ACCOUNT: 161	Liquid flow rate	756.52	GPM	
			Fluid head	20.00	FEET	
			Design temperature	298.99	DEG F	
			Speed	3600.00	RPM	
			Driver power	3.000	HP	
			Fluid viscosity	0.00000200	CPOISE	
			Design gauge pressure	262.00	PSIG	
			Driver type	MOTOR		
			Seal type	SNGL		
			Total weight	630	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	8100.	1.0000	542.	0.0669	23	0.067
PIPING	16439.	2.0295	6255.	0.7722	256	0.380
CIVIL	190.	0.0235	574.	0.0709	30	3.019
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	7067.	0.8725	2081.	0.2569	80	0.294
ELECTRICAL	674.	0.0832	1013.	0.1250	42	1.503
INSULATION	3205.	0.3957	2404.	0.2967	113	0.750
PAINT	247.	0.0304	572.	0.0706	31	2.320
SUBTOTAL	35922.	4.4349	13440.	1.6592	575	0.374

TOTAL MATERIAL AND MANPOWER COST =USD 49400. INST'L COST/PE RATIO = 6.099

A R E A B U L K R E P O R T

ORIGIN	ITEM SYMBOL	DESCRIPTION / DESIGN DATA		MATERIAL COST-USD	MANPOWER MANHOURS	MANPOWER COST-USD	TOTAL DIRECT COST-USD
AREA		MISC CONCRETE ITEMS		707.	133	2590.	3297.
AREA		PIPE TESTING		0.	222	5564.	5564.
GRADE		UNPAVED AREA		8552.	127	2997.	11549.
		Area length	50.000 FEET				
		Area width	50.000 FEET				
AREA		INSTRUMENT TESTING		0.	100	2611.	2611.
AREA		INSTR. RUNS,TRAYS,JBOX.		2200.	49	1150.	3350.
AREA		EQUIPMENT GROUNDING		251.	14	311.	562.
AREA		PILED FOUNDATION		10802.	83	1638.	12440.
		Number of piles	14				
AREA		ELECTRICAL TESTING		0.	17	425.	425.
AREA		ROTATING EQP SPARE PARTS		1100.	0	0.	1100.

APPENDIX IV

ASPEN IPE CAPITAL ESTIMATE REPORT FOR THE MONOCHLOROBENZENE SEPARATION PROCESS

Selected portions of the

List of Equipment and Bulk Material by Area

and the

Contract Summary

C O N T R A C T S U M M A R Y

PRIME CONTRACTOR (CONTRACT NO. 1)

NO.	ITEM	DESIGN ENG'G AND PROCUREMENT K-USD	CONSTRUCTION MATERIAL K-USD	CONSTRUCTION MANHOURS	CONSTRUCTION MANPOWER K-USD	CONSTRUCTION INDIRECTS K-USD	MISC. AND ALL SUBCONTRACTS K-USD *	AMOUNT K-USD	PERCENT OF CONTRACT TOTAL
1	PURCHASED EQUIPMENT	-	206.7	-	-	-	-	206.7	9.2
2	EQUIPMENT SETTING	-	-	339.	8.1	-	-	8.1	0.4
3	PIPING	-	112.8	4432.	108.6	-	-	221.4	9.8
4	CIVIL	-	26.5	987.	19.1	-	-	45.6	2.0
5	STEEL	-	21.3	438.	8.9	-	-	30.2	1.3
6	INSTRUMENTATION	-	182.8	2815.	74.0	-	-	256.8	11.4
7	ELECTRICAL	-	23.4	507.	12.0	-	-	35.4	1.6
8	INSULATION	-	45.9	2011.	42.7	-	-	88.6	3.9
9	PAINT	-	3.2	397.	7.3	-	-	10.6	0.5
10	OTHER	602.9	63.8	-	0.0	482.3	-	1149.0	51.0
11	SUBTOTAL	602.9	686.3	11926.	280.9	482.3	-	2052.4	91.1
12	SUBCONTRACTS	-	-		-	-	0.0	0.0	0.0
13	G AND A OVERHEADS	0.0	20.6		8.4	14.5	0.0	43.5	1.9
14	CONTRACT FEE	51.2	26.2		28.9	49.7	0.0	156.0	6.9
15	BASE TOTAL	654.1	733.1		318.2	546.4	0.0	2251.9	100.0
16	ESCALATION	0.0	0.0		0.0	0.0	0.0	0.0	0.0
17	CONTINGENCIES	117.7	132.0		57.3	98.4	0.0	405.3	18.0
18	TOTAL	771.9	865.0		375.5	644.8	0.0	2657.3	118.0

* NO SUBCONTRACTS

C O M P O N E N T L I S T

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA			PURCHASED EQUIPMENT COST USD
Equipment mapped from 'A1'.						
TW - 1 TRAYED	A1-tower		Shell material	A 515		25700
	CODE OF ACCOUNT:	111	Number of trays	15		
	TAG NO.: A1-tower		Vessel diameter	1.500	FEET	
			Vessel tangent to tangent height	42.00	FEET	
			Design temperature	301.04	DEG F	
			Design gauge pressure	35.30	PSIG	
			Application	DISTIL		
			Tray type	SIEVE		
			Tray spacing	24.00	INCHES	
			Tray material	A285C		
			Tray thickness	0.188	INCHES	
			Base material thickness	0.438	INCHES	
			Total weight	6100	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING:	25700.	1.0000	599.	0.0233	25	0.023
PIPING	11368.	0.4423	16244.	0.6321	660	1.429
CIVIL	1082.	0.0421	1626.	0.0633	84	1.503
STRUCTURAL STEEL	6200.	0.2413	2436.	0.0948	120	0.393
INSTRUMENTATION	39952.	1.5546	20107.	0.7824	760	0.503
ELECTRICAL	1307.	0.0509	791.	0.0308	34	0.605
INSULATION	5684.	0.2212	5573.	0.2169	262	0.980
PAINT	511.	0.0199	1149.	0.0447	62	2.250
SUBTOTAL	91806.	3.5722	48525.	1.8881	2007	0.529

TOTAL MATERIAL AND MANPOWER COST =USD 140300. INST'L COST/PE RATIO = 5.459

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA			PURCHASED EQUIPMENT COST USD
Equipment mapped from 'D1'.						
TW - 2 TRAYED	D1-tower		Shell material	A 515		72500
	CODE OF ACCOUNT:	111	Number of trays	30		
	TAG NO.: D1-tower		Vessel diameter	3.000	FEET	
			Vessel tangent to tangent height	72.00	FEET	
			Design temperature	353.02	DEG F	
			Design gauge pressure	35.30	PSIG	
			Application	DISTIL		
			Tray type	SIEVE		
			Tray spacing	24.00	INCHES	
			Tray material	A285C		
			Tray thickness	0.188	INCHES	
			Base material thickness	0.500	INCHES	
			Total weight	23700	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING:	72500.	1.0000	2237.	0.0308	93	0.031
PIPING	23610.	0.3257	16724.	0.2307	687	0.708
CIVIL	1357.	0.0187	1911.	0.0264	99	1.408
STRUCTURAL STEEL	10818.	0.1492	4345.	0.0599	214	0.402
INSTRUMENTATION	44164.	0.6092	20308.	0.2801	768	0.460
ELECTRICAL	2530.	0.0349	1357.	0.0187	59	0.536
INSULATION	10890.	0.1502	10184.	0.1405	481	0.935
PAINT	807.	0.0111	1631.	0.0225	88	2.020
SUBTOTAL	166677.	2.2990	58695.	0.8096	2489	0.352

TOTAL MATERIAL AND MANPOWER COST =USD 225400. INST'L COST/PE RATIO = 3.109

C O M P O N E N T L I S T

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'D1'.					
HE -	3 FIXED T S	D1-cond	Tube material	A 214	14700
		CODE OF ACCOUNT: 261	Heat transfer area	154.20 SF	
		TAG NO.: D1-cond	Shell material	A285C	
			TEMA type	BEM	
			Shell design gauge pressure	35.30 PSIG	
			Shell design temperature	255.39 DEG F	
			Shell diameter	8.000 INCHES	
			Shell length	20.00 FEET	
			Tube design gauge pressure	60.30 PSIG	
			Tube design temperature	255.39 DEG F	
			Tube outside diameter	1.000 INCHES	
			Tube length extended	20.00 FEET	
			Total weight	1800 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	14700.	1.0000	924.	0.0629	38	0.063
PIPING	11741.	0.7987	8714.	0.5928	358	0.742
CIVIL	795.	0.0540	1261.	0.0858	66	1.587
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	8666.	0.5895	3325.	0.2262	128	0.384
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	3507.	0.2386	3234.	0.2200	152	0.922
PAINT	261.	0.0178	606.	0.0412	33	2.319
SUBTOTAL	39670.	2.6987	18063.	1.2288	775	0.455

TOTAL MATERIAL AND MANPOWER COST =USD 57700. INST'L COST/PE RATIO = 3.925

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'D1'.					
HT -	4 HORIZ DRUM	D1-cond acc	Shell material	A 515	9300
		CODE OF ACCOUNT: 114	Liquid volume	237.96 GALLONS	
		TAG NO.: D1-cond acc	Vessel diameter	3.000 FEET	
			Vessel tangent to tangent length	4.500 FEET	
			Design temperature	254.98 DEG F	
			Design gauge pressure	35.30 PSIG	
			Application	CONT	
			Base material thickness	0.313 INCHES	
			Total weight	1500 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	9300.	1.0000	598.	0.0643	25	0.064
PIPING	8758.	0.9417	9217.	0.9911	376	1.052
CIVIL	1185.	0.1274	1637.	0.1760	85	1.382
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	19355.	2.0812	4218.	0.4536	159	0.218
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	2844.	0.3058	3140.	0.3377	147	1.104
PAINT	210.	0.0226	525.	0.0564	28	2.496
SUBTOTAL	41652.	4.4788	19335.	2.0790	820	0.464

TOTAL MATERIAL AND MANPOWER COST =USD 61000. INST'L COST/PE RATIO = 6.559

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.					
CP -	5 CENTRIF	D1-reflux pump	Casing material	CS	4400
		CODE OF ACCOUNT: 161	Liquid flow rate	37.32 GPM	
		TAG NO.: D1-reflux pu	Fluid head	225.00 FEET	
			Design temperature	254.98 DEG F	
			Speed	3600.00 RPM	
			Driver power	3.000 HP	
			Fluid viscosity	0.267 CPOISE	
			Design gauge pressure	35.30 PSIG	
			Driver type	MOTOR	
			Seal type	SNGL	
			Total weight	270 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING:	4400.	1.0000	240.	0.0544	10	0.054
PIPING	2717.	0.6176	5344.	1.2146	217	1.967
CIVIL	190.	0.0432	574.	0.1305	30	3.019
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	5475.	1.2443	2081.	0.4729	80	0.380
ELECTRICAL	674.	0.1532	1013.	0.2302	42	1.503
INSULATION	1663.	0.3779	1854.	0.4213	87	1.115
PAINT	87.	0.0198	243.	0.0553	13	2.791
SUBTOTAL	15206.	3.4560	11349.	2.5793	479	0.746

TOTAL MATERIAL AND MANPOWER COST =USD 26600. INST'L COST/PE RATIO = 6.045

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.					
QUOTE					
EQP-	7	D1-overhead split	Number of identical items	1	0
		CODE OF ACCOUNT: 100			
		TAG NO.: D1-overhead			

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.					
QUOTE					
EQP-	8	D1-bottoms split	Number of identical items	1	0
		CODE OF ACCOUNT: 100			
		TAG NO.: D1-bottoms s			

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'D1'.					
RB -	8 U TUBE	D1-reb	Tube material	A 214	29300
		CODE OF ACCOUNT: 262	Heat transfer area	918.29 SF	
		TAG NO.: D1-reb	Shell material	A285C	
			TEMA type	BKU	
			Shell design gauge pressure	68.64 PSIG	
			Shell design temperature	353.02 DEG F	
			Shell diameter	39.00 INCHES	
			Shell length	13.00 FEET	
			Tube port diameter	26.00 INCHES	
			Tube design gauge pressure	110.30 PSIG	
			Tube design temperature	377.80 DEG F	
			Tube outside diameter	1.000 INCHES	
			Tube length extended	20.00 FEET	
			Total weight	9100 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING:	29300.	1.0000	784.	0.0267	32	0.027
PIPING	11066.	0.3777	10526.	0.3592	429	0.951
CIVIL	1270.	0.0434	1718.	0.0586	89	1.352
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	15161.	0.5174	5612.	0.1915	215	0.370
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	5203.	0.1776	4892.	0.1670	231	0.940
PAINT	263.	0.0090	649.	0.0222	35	2.465
SUBTOTAL	62264.	2.1250	24180.	0.8253	1031	0.388

TOTAL MATERIAL AND MANPOWER COST =USD 86400. INST'L COST/PE RATIO = 2.949

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'F1'.					
VT - 9	CYLINDER	F1-flash vessel	Shell material	A 515	13100
		CODE OF ACCOUNT: 113	Liquid volume	634.56 GALLONS	
		TAG NO.: F1-flash ves	Vessel diameter	3.000 FEET	
			Vessel tangent to tangent height	12.00 FEET	
			Design temperature	320.00 DEG F	
			Design gauge pressure	35.30 PSIG	
			Application	CONT	
			Base material thickness	0.313 INCHES	
			Total weight	2600 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	13100.	1.0000	599.	0.0457	25	0.046
PIPING	13120.	1.0015	9627.	0.7349	394	0.734
CIVIL	936.	0.0714	1401.	0.1069	73	1.497
STRUCTURAL STEEL	4260.	0.3252	2133.	0.1628	105	0.501
INSTRUMENTATION	25289.	1.9305	4465.	0.3408	169	0.177
ELECTRICAL	675.	0.0516	455.	0.0347	20	0.674
INSULATION	4336.	0.3310	4076.	0.3111	192	0.940
PAINT	399.	0.0305	847.	0.0646	46	2.120
SUBTOTAL	62115.	4.7416	23602.	1.8017	1024	0.380

TOTAL MATERIAL AND MANPOWER COST =USD 85700. INST'L COST/PE RATIO = 6.542

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'H1'.					
HE - 10	JACKETED	H1	Material	CS	7300
		CODE OF ACCOUNT: 263	Heat transfer area	58.23 SF	
		TAG NO.: H1	Tube length	20.00 FEET	
			Number of tubes per shell	1	
			Design gauge pressure	110.30 PSIG	
			Temperature	377.80 DEG F	
			Number of sections	3	
			Total weight	2670 LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	7300.	1.0000	965.	0.1322	40	0.132
PIPING	11265.	1.5431	8688.	1.1901	357	0.771
CIVIL	767.	0.1051	1226.	0.1680	64	1.598
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	6429.	0.8807	1895.	0.2596	69	0.295
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	4273.	0.5854	3767.	0.5160	177	0.881
PAINT	261.	0.0358	606.	0.0830	33	2.319
SUBTOTAL	30296.	4.1501	17146.	2.3488	740	0.566

TOTAL MATERIAL AND MANPOWER COST =USD 47400. INST'L COST/PE RATIO = 6.493

ORIGIN	ITEM TYPE	ITEM DESCRIPTION		DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'H2'.						
HE - 11	FLOAT HEAD	H2	Tube material	A 214		20500
		CODE OF ACCOUNT: 261	Heat transfer area	195.80	SF	
		TAG NO.: H2	Shell material	A285C		
			TEMA type	BES		
			Shell design gauge pressure	35.30	PSIG	
			Shell design temperature	353.02	DEG F	
			Shell diameter	10.00	INCHES	
			Shell length	22.00	FEET	
			Tube design gauge pressure	60.30	PSIG	
			Tube design temperature	353.02	DEG F	
			Tube outside diameter	1.000	INCHES	
			Tube length extended	20.00	FEET	
			Total weight	2300	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	20500.	1.0000	960.	0.0468	40	0.047
PIPING	16426.	0.8013	9826.	0.4793	404	0.598
CIVIL	805.	0.0393	1275.	0.0622	67	1.583
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	8667.	0.4228	3333.	0.1626	128	0.385
ELECTRICAL	0.	0.0000	0.	0.0000	0	0.000
INSULATION	5858.	0.2858	4202.	0.2050	197	0.717
PAINT	359.	0.0175	826.	0.0403	45	2.305
SUBTOTAL	52615.	2.5666	20423.	0.9962	881	0.388

TOTAL MATERIAL AND MANPOWER COST =USD 73000. INST'L COST/PE RATIO = 3.561

ORIGIN	ITEM TYPE	ITEM DESCRIPTION		DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'M1'.						
QUOTE						
EQP- 14		M1	Number of identical items	1		0
		CODE OF ACCOUNT: 100				
		TAG NO.: M1				

ORIGIN	ITEM TYPE	ITEM DESCRIPTION		DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'S1'.						
QUOTE						
EQP- 15		S1	Number of identical items	1		0
		CODE OF ACCOUNT: 100				
		TAG NO.: S1				

ORIGIN	ITEM TYPE	ITEM DESCRIPTION		DESIGN DATA		PURCHASED EQUIPMENT COST USD
Equipment mapped from 'P1'.						
CP - 13	CENTRIF	P1	Casing material	CS		3300
		CODE OF ACCOUNT: 161	Liquid flow rate	22.73	GPM	
		TAG NO.: P1	Fluid head	62.10	FEET	
			Design temperature	250.00	DEG F	
			Speed	3600.00	RPM	
			Driver power	1.500	HP	
			Fluid viscosity	0.583	CPOISE	
			Design gauge pressure	60.30	PSIG	
			Driver type	MOTOR		
			Seal type	SNGL		
			Total weight	210	LBS	

ITEM	MATERIAL USD	MATERIAL FRACTION OF PE	MANPOWER USD	MANPOWER FRACTION OF PE	MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	3300.	1.0000	240.	0.0726	10	0.073
PIPING	2717.	0.8235	5344.	1.6195	217	1.967
CIVIL	176.	0.0533	547.	0.1659	28	3.115
STRUCTURAL STEEL	0.	0.0000	0.	0.0000	0	0.000
INSTRUMENTATION	5475.	1.6591	2081.	0.6305	80	0.380
ELECTRICAL	674.	0.2042	1013.	0.3069	42	1.503
INSULATION	1621.	0.4912	1817.	0.5507	86	1.121
PAINT	87.	0.0264	243.	0.0738	13	2.791
SUBTOTAL	14050.	4.2576	11286.	3.4199	476	0.803

TOTAL MATERIAL AND MANPOWER COST =USD 25300. INST'L COST/PE RATIO = 7.667

C O M P O N E N T L I S T

ORIGIN	ITEM TYPE	ITEM DESCRIPTION	DESIGN DATA		PURCHASED: EQUIPMENT: COST USD
Equipment mapped from 'T1'.					
QUOTE					
EQP- 19		T1	Number of identical items	1	0
		CODE OF ACCOUNT: 100			
		TAG NO.: T1			

A R E A B U L K R E P O R T

ORIGIN	ITEM SYMBOL	DESCRIPTION / DESIGN DATA		MATERIAL COST-USD	MANPOWER MANHOURS	MANPOWER COST-USD	TOTAL DIRECT COST-USD
AREA		MISC CONCRETE ITEMS		918.	173	3354.	4272.
AREA		PIPE TESTING		0.	335	8381.	8381.
GRADE		UNPAVED AREA		8552.	127	2997.	11549.
		Area length	50.000 FEET				
		Area width	50.000 FEET				
AREA		INSTRUMENT TESTING		0.	179	4672.	4672.
AREA		INSTR. RUNS,TRAYS,JBOX.		4132.	81	1943.	6075.
AREA		EQUIPMENT GROUNDING		419.	23	519.	938.
AREA		PILED FOUNDATION		16974.	131	2575.	19549.
		Number of piles	22				
AREA		ELECTRICAL TESTING		0.	22	548.	548.
AREA		ROTATING EQP SPARE PARTS		540.	0	0.	540.